Illinois Space Society Tech Team

NASA USLI
Preliminary Design Review

Table of Contents

1. Summary....3
    1.1 Team Summary
    1.2 Launch Vehicle Summary
    1.3 Payload Summary

2. Changes Since Proposal....4

3. Vehicle Criteria....5
    3.1 Vehicle Selection, Design, and Verification
    3.2 Recovery Subsystem
    3.3 Mission Performance Predictions
    3.4 Interfaces and Integration
    3.5 Launch Procedures
    3.6 Safety and Environment

4. Payload Criteria....33
    4.1 Payload Selection, Design, and Verification
    4.2 Payload Concept
    4.3 Science Value
    4.4 Safety and Environment

5. Project Plan....46
    5.1 Budget
    5.2 Funding
    5.3 Project Timeline
    5.4 Educational Outreach

6. Conclusion....53

7. Appendices....54

1. Summary

1.1 Team Summary

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1.2 Launch Vehicle Summary

The rocket chosen for this project is the Wildman Rocketry Ultimate Darkstar kit. This kit is a six inch diameter rocket with a final length of 150 inches. All kit components except centering rings are fiberglass. The final assembled mass of the rocket, including payload and motor, is anticipated to be approximately 42 pounds.

Using simulations approximating the mass of the rocket, the projected total impulse of the motor will be at least 4500 Ns, depending on the final weight of the rocket. The motor supplier chosen was Aerotech, which provides a good selection of motors around this size. Preliminarily, the motor chosen is the Aerotech L2200, a 75 mm motor with a total impulse of 5104 Ns. For launch, the rocket will be mounted onto a standard 1515 launch rail that is 8 ft in height.

The rocket will have a dual deployment recovery system, utilizing redundant Stratologger and Telemetrum Altimeters. The altimeters will be contained in the coupler, separate from all transmitters and other payload electronics. Each altimeter will have an independant arming switch and battery. Each altimeter will be configured to deploy a drogue parachute at apogee and a main at 800 feet AGL.

1.3 Payload Summary

The payload for this rocket is a deployable quadrotor Unmanned Aerial Vehicle. The UAV will fold to fit inside the rocket during ascent. This folded shape will be maintained during the ascent stage of flight. When the rocket reaches apogee, the drogue chute will be deployed, and the recovery harness will pull the UAV out of the rocket. Upon receiving safety confirmation from the RSO, a trigger to release the UAV will be initiated by the ground team. The UAV will then fly autonomously and record video. The UAV will also include a GPS tracking device that will be able to transmit location data to a ground station.

2. Changes Since Proposal

As noted in the Addendum to the Proposal, the team is no longer pursuing to complete the SMD payload requirements. The primary engineering payload, the UAV quadrotor, is still being fully pursued, but without the necessary science instruments to complete the SMD payload goals. This is due to funding constraints, but will also allow for more time to work on necessary components of the UAV system.

The change in payload will not affect the flight design of the UAV. It will, however, make it lighter and more efficient. Removing the science instruments necessary to complete SMD payload requirements also decreases the complexity of the final design, lowers build time and reduces the workload on the payload team. Safety features originally included as part of the UAV, including gps locators, will not be affected by this change in payload.

The activity plans remain largely unchanged. Looking at the mechanical design of the UAV we changed the unfolding mechanism on the base from having two arms connected to torsion springs to all four arms being connected. This will allow the center worm gear to spin without any resistance created by the quadrotor arms. Rather than machining this base from aluminum, we are looking to print it out on a 3D printer. This will save us machining and material costs while helping us create a lightweight yet strong nylon base.

With regards to the UAV hardware, a large change was made to the design by incorporating a Raspberry Pi computer onboard the quadrotor. This will allow the UAV to process and compute all mission critical tasks immediately without the need to transmit wireless data to a ground station. The Raspberry Pi computer will be communicating with the Parallax Propeller chip over a UART connection therefore allowing us to stick our original plans for motor control and sensor readings.

3. Vehicle Criteria

3.1 Vehicle Selection, Design, and Verification

A. Mission Statement

Safely launch and recover a high power rocket with an Unmanned Aerial Vehicle payload, consisting of an autonomous folding quadrotor with mounted cameras, while successfully completing competition requirements.

B. Requirements

In order to successfully complete the mission statement, a number of conditions must be met by the launch vehicle. The main requirements of the rocket structure, including recovery systems, are dictated by mission goals for the payload and NASA requirements, and are listed below.

1. The rocket will be integratable with the UAV payload
2. The rocket shall meet all competition flight requirements, including but not limited to:
    i. The rocket will reach 5280 but not exceed an apogee of 5600 feet AGL
    ii. The rocket will consist of no more than 4 independent sections
    iii. The rocket will not go supersonic
    iv. The rocket will use standard 1515 launch rails 8 feet in height
3. The rocket will utilize a dual deployment parachute system
4. The vehicle will include one commercially available barometric altimeter for official scoring
5. Each altimeter will be independently armed and have a dedicated power supply
6. Each altimeter will be capable of being locked in the on position
7. The vehicle will land within 2,500 feet of the launch pad given a 15 mph wind, and each vehicle section will land with a kinetic energy of less than 75 ft-lbf
8. The total impulse of the rocket motor shall not exceed 5120 Ns.
9. The max. cost of the vehicle and payload as flown for the competition will not exceed $5000
10. The vehicle must be recoverable and reusable without additional repairs.

C. Mission Success Criteria

The mission will be successful upon completion of the competition if, while maintaining the highest possible safety standards, all mission requirements are satisfied, all competition goals are met, and the rocket successfully allows the payload to meet its design goals.

D. Rocket Design and Analysis

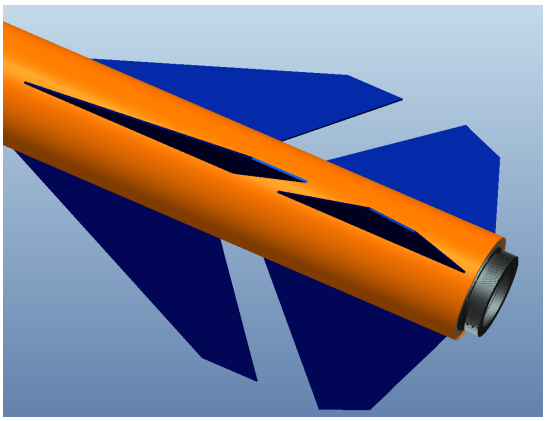
The vehicle chosen for this competition is the Wildman Ultimate Darkstar. This kit is a six inch diameter, eighty inch tall rocket. The rocket has four segments: a booster airframe, a coupler with a switchband, an upper airframe, and a nosecone. Each of these sections will be examined in detail following

Figure 3.1: Assembled Rocket Structure

E. Booster Airframe Analysis

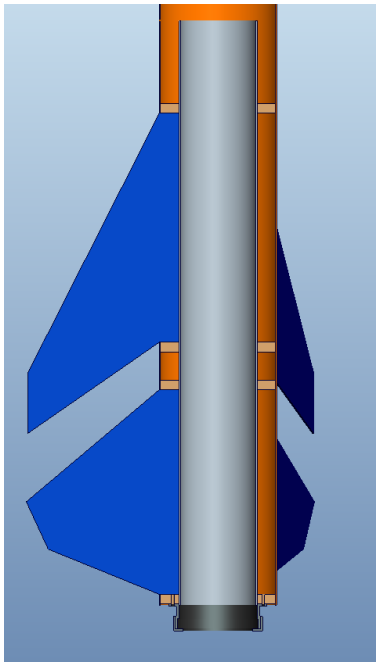
The booster airframe contains a number of subsystems, including the fin assembly, motor casing and retainer, and launch rail interface.

Figure 3.2: Booster Airframe



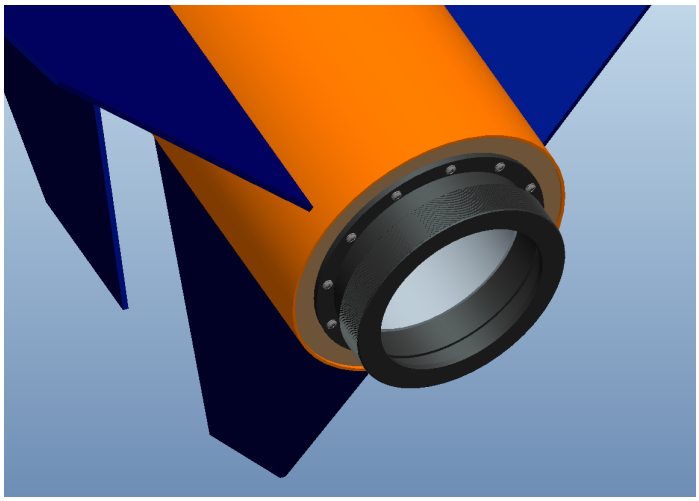
The fins of the rocket consist of three split fins, or six total fins. Fin slots were put in the airframe by the manufacturer. The fins are designed to mount on the motor mount and airframe. The fins will be placed between the centering rings, to help increase the structural integrity of the fin assembly. As the fins will undergo some of the largest aerodynamic loadings, they will be carefully mounted and epoxied to these surfaces to decrease the chance of one of them fluttering and/or detaching during flight.

Figure 3.3: Fin Assembly



The motor assembly for this kit consists of a fiberglass motor mount, wood centering rings, Aeropack motor retainer and adapter, and a motor casing. When fully assembled, the centering rings are mounted to the motor mount at locations just above and below all six fins, with the motor retainer attached to the lower centering ring. The wooden centering rings are secured in place with epoxy fillets on both top and bottom sides. The method of attachment for the retainer is 12 screws with threaded inserts mounted into the centering ring.

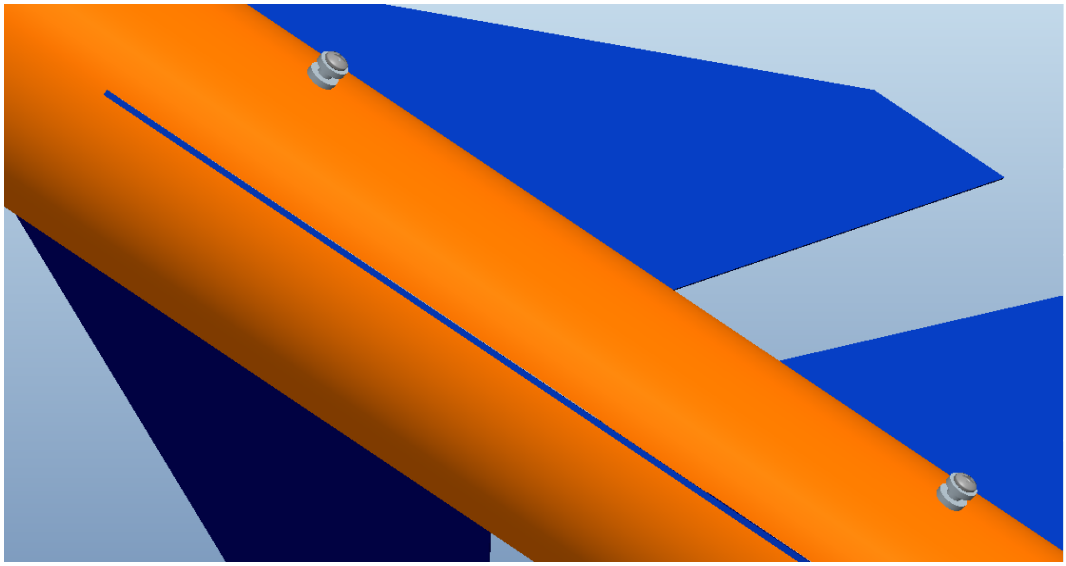
Figure 3.4: Motor Retainer Assembly



The launch rail interface for the rocket is three 1515 rail buttons attached to the side of the booster airframe. These rail buttons will be attached via screws to a threaded nut in the rocket. The threaded nut will be mounted on plywood and epoxied to the rocket. This setup ensures that the button will be fixed to the rocket, and will also allow for the

attachment of replacement buttons should one or more be removed or damaged.

Figure 3.5: Rail Button Arrangement

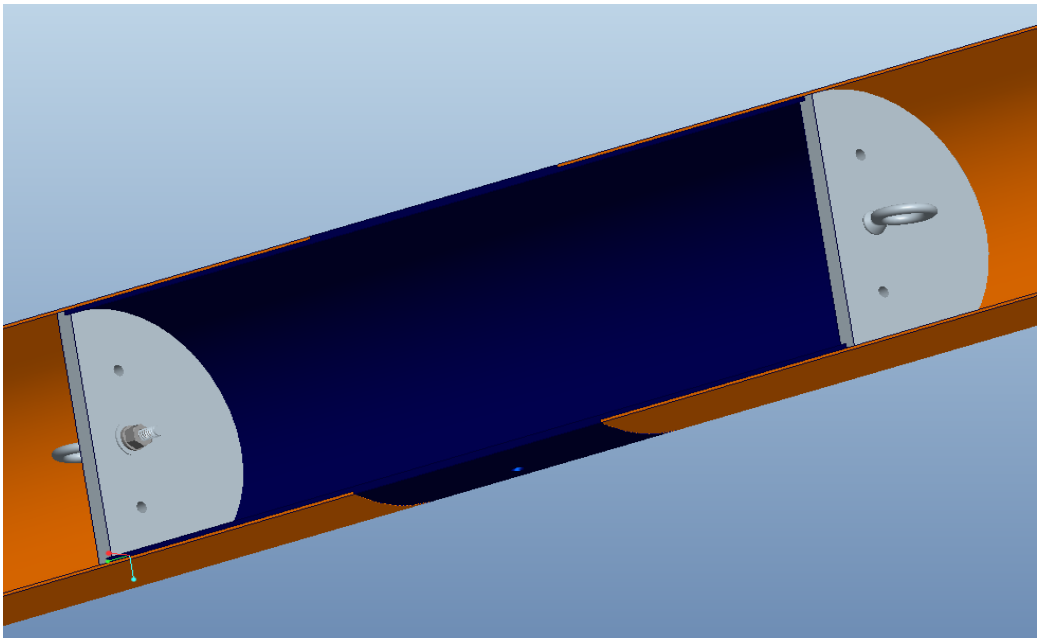


The drogue parachute will also go into the booster airframe with the quadrotor UAV engineering payload above it. The UAV itself is designed to fit securely against the walls of the rocket body, and has no impact on the structural component of the actual launch vehicle.

F. Coupler Analysis

The fiberglass coupler provided with the kit will contain the electronics, and will serve as a mounting location for the black powder ejection charges. The electronics, mounted on a sled, will slide into the coupler where it will be secured to the top bulkhead via threaded nut and washer. The sled is made of aircraft grade plywood which will also have 4 pieces of copper tubing epoxied to the side of the sled opposite of the electronics. The backup and main Stratologger altimeter, Altus Metrum Telemetrum, and individual batteries will be mounted on the electronics sled. The sled will slide over two threaded rods that span the entire length of the payload bay which are secured in place with threaded nuts and washers. Three switches are mounted to the outside of the switch band and are connected to the three electronic components to individually control each of them. The entire coupler system and payload will be connected to the upper airframe and booster airframe via 8 total shear pins.

Figure 3.6: Coupler with Bulkheads



G. Upper Airframe Analysis

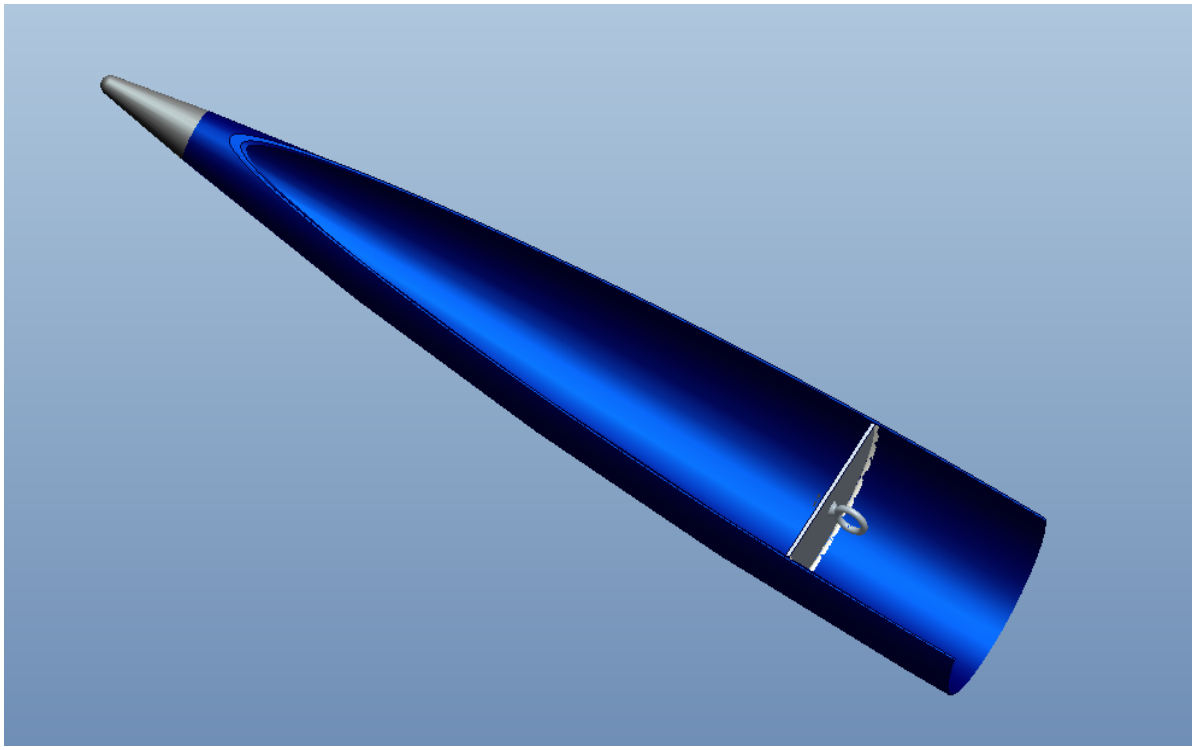
The upper airframe serves as housing for the main parachute. The parachute will be attached via elastic shock cord to the eyebolts. Protective recovery wadding will separate the black powder charge and the parachute to prevent damage to the parachute. The upper airframe will be attached to the nosecone via 4 shear pins.

H. Nosecone Analysis

The nosecone provided with the kit is the 5.5-1 von Kármán filament wound fiberglass nose cone with aluminum tip. The von Kármán geometry gives minimum drag for a given length and diameter, while the aluminum tip reinforces the nose cone and prevents the tip from shattering upon descent. A fiberglass bulkhead was epoxied in place for parachute attachment on the inside of the nose cone. A forged eyebolt is secured with nut and washer to the center of the bulkhead. This forged eyebolt will serve as the upper connection for the main parachute.

Before mounting the bulkhead to the nosecone, the eyebolt was mounted to the bulkhead and epoxied in place to prevent it from moving. In order to secure the bulkhead in place, fillets of epoxy were placed above and below the bulkhead along the connections to the nosecone body. The only future work on the nosecone is drilling holes for connecting the upper airframe to the nosecone.

Figure 3.7: Nosecone Assembly



I. Verification Plan

Table 3.1: Verification Plan and Status

Requirement	Verification Plan	Status
Vehicle shall deliver engineering payload to 5280 ft AGL	Modelling, simulation and flight testing of rocket and motor	Simulations complete, preparing for flight tests
Vehicle shall carry one commercially available barometric altimeter for competition scoring	Inspection; recovery system currently includes multiple possible altimeters	Complete
The official scoring altimeter shall report altitude as a series of beeps	Inspection; recovery system currently includes such altimeters	Complete
All audible electronics except the official scoring altimeter will be capable of being turned off after launch	Inspection and ground testing; team will verify payload meets requirement after construction	Incomplete, awaiting avionics bay construction
The launch vehicle shall remain subsonic	Modelling, simulation and flight testing of rocket	Current simulations suggest model will remain subsonic for duration of flight, awaiting validation through testing
The launch vehicle shall be reusable and recoverable	Inspection; all components and systems of rocket are intended to be reusable	Rocket is designed to be recoverable, demonstration will be first test flight
The launch vehicle will have a maximum of four independent sections	Inspection; the rocket currently has four independent sections	Complete

The launch vehicle will be capable of being prepared within 2 hours	Ground testing to verify team can assemble rocket quickly	Incomplete, awaiting payload construction
The launch vehicle will be able to remain on the for a minimum of 1 hour	Ground testing to verify all components can remain ready for one hour	Incomplete
The vehicle shall be compatible with an 8 ft 1.5 inch launch rail	Inspection; vehicle is using 1515 rail buttons	Complete
The launch vehicle shall be capable of launching with a standard 12 V firing system	Inspection; the rocket will only use motors compatible with the standard system	Complete
The vehicle shall require no external circuitry or special ground support equipment to initiate launch	Inspection; current designs do not call for any such equipment	Complete
The rocket shall use commercially available solid rocket motors	Inspection; the rocket is only using commercially available motors	Complete
The total impulse installed on the rocket shall not exceed 5120 Ns	Inspection; no larger motors will be used	Complete
The ballast of the fully configured rocket shall not exceed 10% of the unballasted weight	Inspection and testing; if ballast is needed, it will not be made to exceed this weight	Incomplete, awaiting flight testing
The rocket will successfully undergo a full scale launch prior to FRR	Inspection and planning; current timeline allows for full scale testing across multiple weeks	Planning, completing construction of rocket and beginning testing
The UAV shall fly as intended during the full scale launch	Inspection; during full scale launch, UAV will be completed	Awaiting construction of UAV, full scale flight
The maximum cost of the rocket on the pad shall not exceed $5000	Planning and inspection; if a part pushes the total cost of the rocket above this limit, that part or another of similar cost will be replaced; the design will allow for this requirement by not including multiple large cost, essential devices	Ongoing; design currently does not exceed this limit
The vehicle shall utilize a dual deployment recovery system	Inspection; the rocket currently includes a dual deployment system	Design complete, awaiting testing
The maximum kinetic energy of each independent section at landing shall not exceed 75 ft-lbf	Modelling and simulation of rocket will include descent rate approximations; data gained from testing will ensure requirements are met	Modelling work complete, awaiting verification through testing
All independent sections of the vehicle shall land within 2500 ft given a 15 mph wind	Modeling of the rocket will provide approximate descent rates to meet this goal, testing will validate models	Modelling work complete, awaiting verification through testing
Recovery system electronics shall be independent of payload circuitry	Inspection; design separates recovery electronics from payload	Complete

The recovery system will have redundant commercially available altimeters	Inspection; the design currently uses three such altimeters	Complete upon construction of payload
Each altimeter will have a dedicated arming switch and power supply	Inspection; design currently meets these requirements	Complete upon construction of payload
Each altimeter will be capable of being locked in the ON position	Testing will be done to make sure switches meet this requirement	Awaiting construction of payload for testing
Each arming switch will be a maximum of 6 feet above the base of the vehicle	Inspection; design puts switches below this limit	Complete
Removable shear pins shall be used for both the drogue and main parachute compartments	Inspection; design uses such shear pins for all connections	Awaiting construction of rocket
Electronic tracking devices shall be installed on all independent sections of the vehicle	Inspection; design calls for such devices on all sections	Awaiting construction of rocket and avionics
The recovery system shall not be adversely affected by any on board electronics during flight	Ground and flight testing will be performed to ensure proper function of all electronics throughout flight	Awaiting payload construction to begin ground testing
The altimeters will be located in a separate compartment from other radio transmitters	Inspection; design currently has sealed container for altimeters	Design meets requirement
The recovery system must be shielded from devices which create magnetic waves	Inspection; the design has sealed container for altimeters, only small magnetic waves produced from UAV motors	Design meets requirement, awaiting testing
The recovery system will use commercially available electric matches for ejection charge ignition	Inspection; no homemade igniters will be used	Complete

J. Risk Mitigation schedule

A risk assessment, including mitigation strategies, is given below for the entire project.

Table 3.2: Risk mitigation and solution table

Risk	Probability	Impact	Solution
Project falls behind schedule	Moderate to High	Work becomes rushed or doesn't get finished	Develop timeline for project requirements and create short term goals to move the team closer to meeting the requirements. Keep team members informed of goals and progress.

Project goes over budget	Moderate	Unable to buy necessary components or spare parts, forcing design changes	Develop thorough design that specifies all needed components, account for spares for critical components, and reuse components from previous projects whenever possible.
Key team members leave project	Low	No one capable of performing specific functions	Make sure at least two team members know how to perform every step necessary to complete project.
Necessary equipment unavailable	Low to Moderate	Unable to work on project until equipment becomes available, or forced design changes	Plan ahead to have equipment available for any construction or computer work, have backup plans so team members always have work.
Necessary components unavailable or ship late	Low to Moderate	Unable to complete project, forcing design changes	Buy necessary components quickly, and when possible buy from suppliers who have component in stock.
Communication problems	Low to Moderate	Team members unaware of responsibilities, tasks do not get finished	Have clear list of duties for each team section, have managers assign clear duties to each team member.
Team members unable to perform duties	Moderate	Not enough team members available to finish task, forcing larger loads on other members	Have more than one team member capable of completing a task, coordinate with all team members on when work should be done.
Bad weather on launch day	Moderate	Unable to complete requirements for competition, or get necessary data for competing	Have backup launch dates scheduled, and schedule necessary launches well in advance of deadlines.

K. Confidence and Maturity of Design

The Illinois Space Society Tech Team is confident in its design work for the rocket for this competition. All design work was made by those experienced with high power rocketry using their experience, calculations and computer simulations. The result of this previous experience along with rigorous testing to guarantee safety gives the design of our rocket maturity.

The sub-scale launch vehicle and sub-scale payload have yet to be built. This will give us better understanding of how the full-scale model will perform through the data it provides. With this data we will make the necessary adjustments to the full-scale vehicle to ensure better performance.

L. Dimensional Drawing of Assembly

Figure 3.8: Exploded View of Rocket

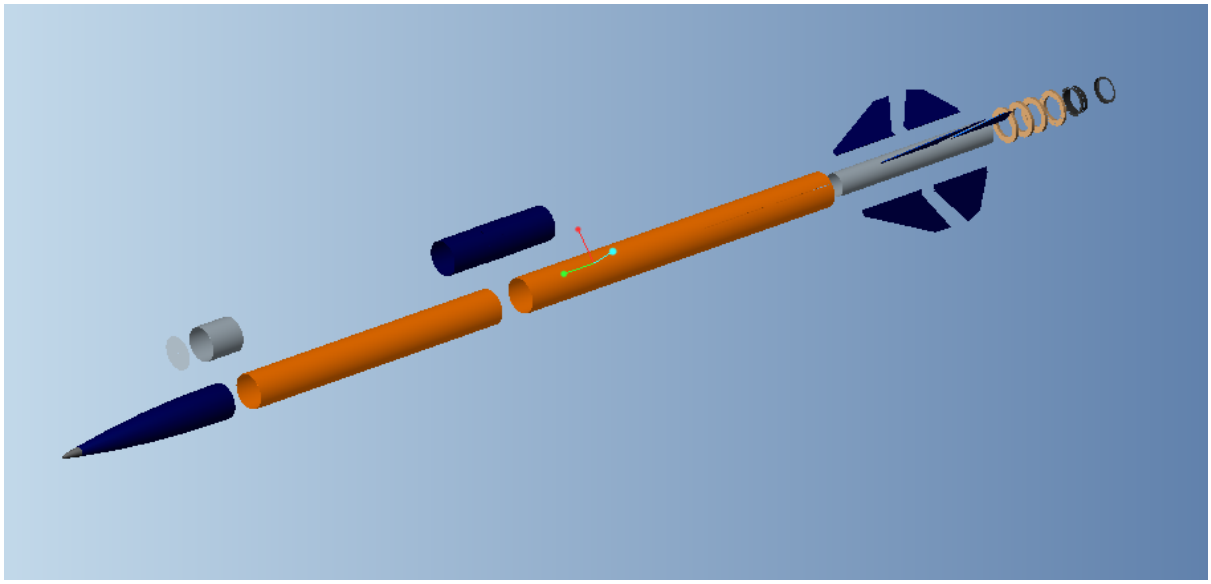
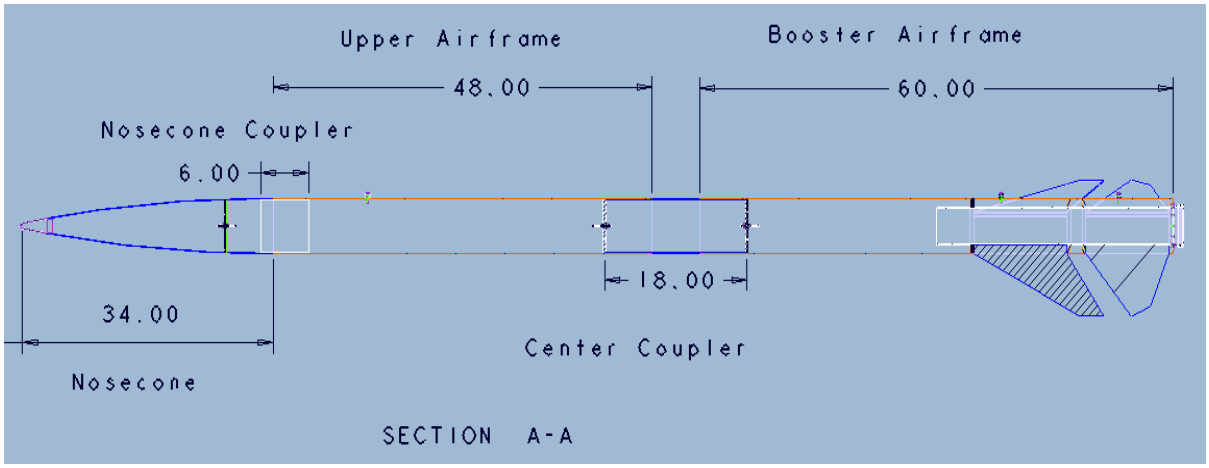


Figure 3.9: Flight Vehicle Dimensions



M. Mass Statement

The mass of the final rocket will be approximately 43 lbs. This mass is calculated from weight measurements of components, approximate weight or stated weight, if given, of components not already delivered, and predicted weight of additional small components. The tabulation of this weight is given below.

Table 3.3: Rocket component masses

Section	Component and quantity	Mass (lbs)
Booster Airframe		
	Body Tube	8.84
	Upper Fin (3)	.83
	Lower Fin (3)	.65
	Centering Ring (4)	.19
	Rail Button and Hardware (3)	.19
	Retainer and Hardware	.59
	Motor Casing	3.71
	Drogue Parachute	.53
	Total	19.44
UAV Payload		
	Projected total mass	3
	Total	3
Coupler		
	Bulkhead and Hardware (2)	.72
	Coupler and Switchband	3.19
	Threaded rod	.23
	Batteries (3)	.1
	Attachment hardware	.74
	Payload sled board	.31

	Total	6.21
Upper Airframe and Nosecone		
	Nosecone	5.01
	Nosecone Bulkhead and hardware	.72
	Upper Body Tube	5.86
	Main Parachute	2.81
	Total	14.4
Total		43.05

The final weight of the rocket is large for an L motor to reach one mile. This is understood, and minimizing the amount of added weight to the rocket has been attempted throughout the design. As such, an emphasis has been placed on smaller components wherever possible.

N. Subscale Model

In order to acquire a better understanding of the rocket and simulation software used, a subscale model of the rocket will be built and flown. This rocket will provide essential data for evaluating the rocket before the first test flight, and will also significantly increase the amount of data to draw on in evaluating the effectiveness of simulations in the future. For this project, a subscale model of the rocket is produced by the same supplier as the full scale rocket. This kit, the Darkstar Mini, includes all necessary components to fly the subscale model successfully and is significantly simpler to build compared to the full scale rocket. As such, the two will be built simultaneously, and will also use similar construction techniques. Results from the subscale launch will be included with the CDR.

3.2 Recovery Subsystem

A. Recovery System Design

Our recovery system will be a dual deployment recovery system with a drogue parachute deploying at apogee and a main parachute at 800 feet. All parachutes will be fired by Perfectflite Stratologger barometric altimeters. One of the altimeters will function as the main deployment altimeter, with no apogee delay set and a main parachute deployment altitude set at 800 feet. The second altimeter will serve as a backup deployment altimeter, firing separate backup charges. This altimeter will have an apogee delay set for the drogue deployment as well as a lower main deployment altitude setting of 700 feet. This system will help ensure that should a problem occur, even if a charge fires but does not completely deploy the parachute, the backup altimeter and charges will be delayed and be able to solve the problem.

The Stratologger is a barometric altimeter that beeps the altitude of apogee, which would allow it to function as an official competition altimeter. Stratologger altimeters have been used considerably in the past by ISS Tech Team members, ensuring team member familiarity with parachute deployment, testing, and data collection from these altimeters. TeleMetrum altimeters have also been used in the past by team members. The

TeleMetrum altimeter has an integrated GPS receiver and transmitter, allowing it to function as the locating device for the 3 tethered components of the rocket. Like the Stratologger, the TeleMetrum is a barometric altimeter.

Each of the altimeters involved in parachute deployment will fire two black powder charges, one for the drogue in the lower airframe of the rocket for drogue deployment, and one in the upper section for main. Each charge will be ignited using e-matches, and charges will be assembled by the team mentor. The ejection charges will be mounted on the bulkheads of the coupler, using tubing that is permanently attached to the rocket. The e-matches will connect to the altimeters through terminal blocks mounted on the same side of the bulkheads. Before deployment, the rocket will be held together by removable shear pins in all sections that will separate. Through calculations which took rocket component mass, force required to break shear pins, and inner rocket volume into account, we arrived on a base estimate for our drogue ejection charges of 6.5 grams, and a main ejection charge of 10.5 grams. It should be noted that these are both early estimates made using common formulas. These will provide a starting point at which to start with ground testing. It is more than likely that both of these will change as the project moves forward toward flight tests. Shear pin estimates put us at using 4 6-32 nylon shear pins at each separation point. Shear pins will be analyzed at ground testing to ensure the charges are large enough to break all pins, but the first flight test will be the true test of the shear pins since drag forces cannot be analyzed as accurately on the ground. Both altimeters and all charges will be tested for continuity before they are launched. The Stratologger automatically does continuity checks once altimeters are turned on, allowing for no further device to be implemented to perform this important safety task.

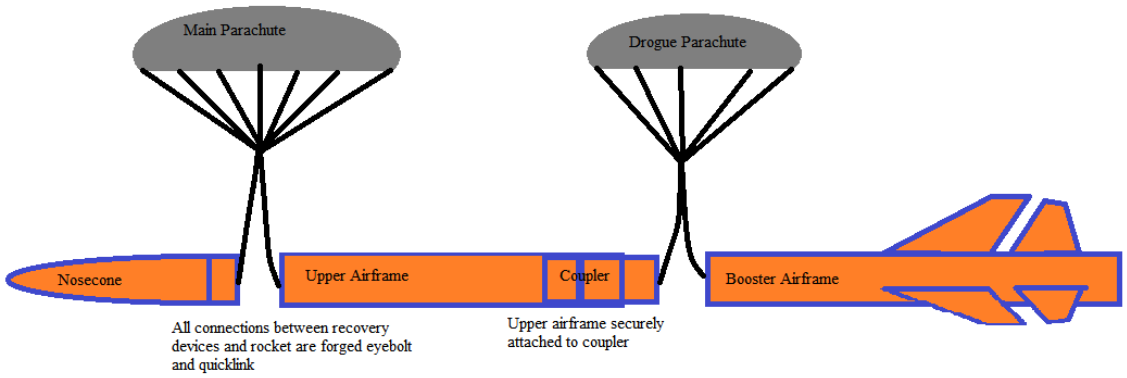
The parachutes that will be used will be sized such that the descent rate under drogue is no faster than 80 ft/s and that the descent rate under main parachute is no faster than 20 ft/s. The descent rate under main and drogue will not allow any independent section of the vehicle to hit the ground with a kinetic energy of more than 75 ft-lbf, which is equivalent to a 15 ft/s descent rate for any 10 lb section. In addition, the descent rate of the vehicle will be determined to allow the vehicle to land within 2500 feet of the pad with a 15 mph wind.

Through careful consideration of parachutes available on the market today, we have decided that a Rocketman 16 ft parachute will serve as our main parachute. The Rocketman line of parachutes have been used by our group before with success. According to data available on the manufacturer's website, this parachute will allow us to maintain less than a 20 ft/s descent rate and come within the kinetic energy guidelines. A 36" SkyAngle parachute will serve as the drogue and will maintain less than 80 ft/s of a descent rate. The data provided by manufacturers and simulations will be corroborated with testing results, which will allow for confirmation of the predicted descent rates. If the descent rates do not match testing results, the calculations will be redone and a new parachute configuration will be chosen, if necessary. Careful consideration was made in the drogue parachute choice, as we needed it be maintain a descent rate below 80 ft/s, but not too far below that mark, as the rocket could then drift too far away. Our team has experience working with SkyAngle parachutes as well and therefore has a firm grasp

around how to use these parachutes properly. The shock cord material will be tubular nylon and all eyebolts will be forged. All connecting gear between the parachutes and the rocket will be inspected to ensure it can withstand the applied loads. All parachutes will also have flame protective covers to prevent burns from ejection charges.

The sequencing of recovery events will be determined by the altimeters. When the altimeters detect apogee, they will trigger the charges in the booster airframe. These charges will ignite, and sever the shear pins connecting the coupler and the booster. The ejection will pull out the shock cord, UAV, and drogue parachute. The main charge will be set to deploy at apogee, while the backup will have a two second delay. This ensures that should anything go wrong with the first charge, the second has a chance of providing an extra push to the rocket. The UAV will initiate its own flight, but the rocket will continue to descend under the drogue until it reaches an altitude of 800 ft AGL. At this altitude, the main altimeter will trigger the deployment of the charge in the upper airframe. This airframe will remain connected to the coupler, as the two are securely bolted together. However, shear pins connecting the upper airframe to the nosecone will be severed. The charge will push out the main parachute, which will slow down the rocket to an acceptable landing speed. If the main charge for any reason does not activate, or is not enough to force out the main parachute, the backup charge will be deployed at 700 ft to push out the parachute. If the parachute is already deployed, the backup will initiate and detonate harmlessly. After main parachute deployment, the rocket will slow to its landing speed and drift to landing. A diagram of the recovery system when deployed is shown below.

Figure 3.10: Deployed recovery system



The parachutes will connect to the rocket using quicklinks and 1'' tubular nylon shock cords. The shock cords will be sized to approximately five times the length of the rocket, about 60 feet for each section, to allow for adequate vehicle separation under parachute and to help reduce any possible spikes in force during deployment. Each parachute will connect to the rocket in two places. The drogue will attach at the bottom to the forward closure of the motor retainer. Aerotech motor retainers have forward closures that allow for the attachment of a forged eyebolt to the casing, and the recovery harness will be quicklinked

to this piece. The drogue will be connected above to the lower bulkhead of the avionics bay, the coupler. This link will also be via a quicklink to a forged eyebolt that is screwed and epoxied to the bulkhead. The main parachute will have a nearly identical connection to the top of the coupler for its lower connection. The upper connection for the main parachute will be a bulkhead epoxied into the nosecone, that also has a forged eyebolt screwed and epoxied into it. All of the forged eyebolts have washers and nuts to retain them and help dissipate loads across the bulkhead.

In addition to the two barometric altimeters, an Altus Metrum TeleMetrum altimeter will also be placed in the altimeter and electronics bay. This device will allow us to receive live telemetry from the rocket during flight, which may be important to our engineering payload and deciding on its release. The additional data will also be very helpful in test flights. This not only satisfies the NASA requirement of GPS tracking, but will also provide a further backup for data, as the competition requires a recorded final altitude.

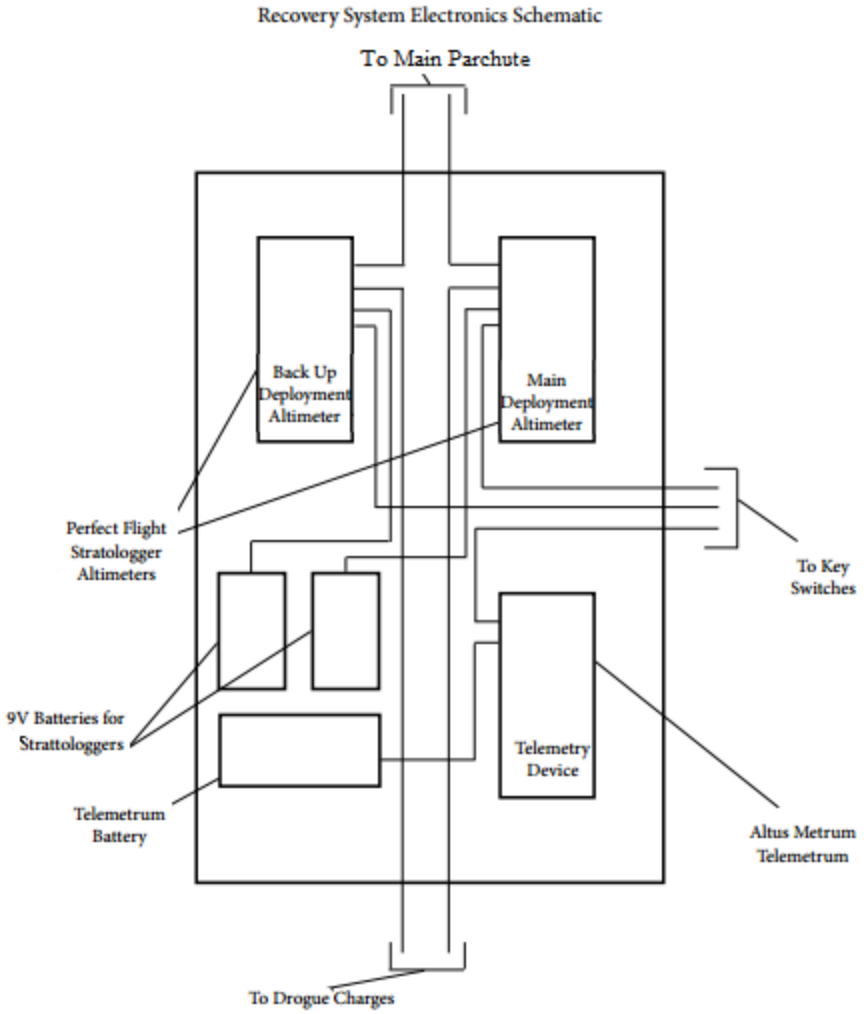
Per NASA safety guidelines, all altimeters will be armed from outside the rocket via key switches located on the switchband of the altimeter and electronics bay, and each will have separate power sources. Each Stratologger will have its own 9V battery, which will be new for every flight, and the Telemetrum will utilize its own rechargeable battery, which will be charged prior to all charges. The key switches will all be located on one vertical line on the side of the rocket, opposite the rail guides. Each key switch has the ability to be locked in either the on or off position. Keys will be kept with launch materials and taken to the launch pad to be used only once the rocket is on the pad. The key switches will connect to the altimeters using stranded wire, to decrease the chances of a wire breaking during integration or flight. All wires will be connected as firmly as possible, and all connections will be double checked before launch to make sure there is a minimal chance of a wire dislodging. Also, per NASA safety guidelines, all e-matches and charges will be stored and handled by our high power certified mentor. All recovery system electronics, namely Stratologger and TeleMetrum altimeters, their power sources, and their switches, will be kept in a separate compartment from payload electronics.

In addition, the vehicle payload and recovery system will be assembled and tested to ensure their non-interference before test flights, and also after any changes to payload or recovery electronics. Their dedicated arming switches are expected to be 5 ft 3 inches above the base of the rocket, at the center of the switchband. This is below the 6 ft height requirement specified by NASA.

B. Schematic of Recovery Electronics

A diagram of the recovery electronics is shown below. The recovery electronics sled shown will be attached to threaded rod in the coupler and screwed in place before flight.

Figure 3.11: Schematic Diagram of Recovery Electronics



C. Testing Procedure

Once the rocket structure is complete, we will begin a regimen of systems tests to assure proper flight performance. For deployment testing, all tests will be done using as many flight components as possible. This means either using the real component intended to be used during launch, or a weight accurate simulant. We will use a weight accurate “dummy” UAV as to not damage it during testing of ejection charges and early launches. The dummy will utilize a mass component that was built for a previous rocket as ballast, and is slightly lighter than the projected weight of the UAV. All tests will be performed with help of our NAR mentor, as he will prepare all charges for us. We will use remote mechanisms to fire all charges during testing in order to maintain a safe distance. Tests will be video recorded for analysis and record keeping.

In addition to tests of the charges, the team will perform thorough analysis and testing of all

flight avionics and transmitters, to ensure no interference is possible at any stage in flight. Interference testing will include actual flight electronics placed in flight ready configuration. The team will analyze each component to ensure that there is no interference between components in their flight ready form. If one or more device is being interfered with, as determined by non-optimal performance or signal discrepancies from individual component testing results, the team will restore optimal function through either changing transmission frequencies or the location of electronics in the rocket. When further testing shows all components are performing as desired, the configuration settings of the electronics will be recorded and not changed before the flight.

3.3 Mission Performance Predictions

To help ensure the rocket will be able to meet system requirements, numerous simulations of the rocket in its final flight configuration have been made. These simulations are intended to provide an indication of the rocket's flight performance characteristics and to verify the safety of the rocket for testing purposes. They are not intended to be used on their own as the sole method of analysis of the rocket, and will be used in conjunction with testing data when that data becomes available.

Table 3.4: Predicted apogee for separate motors

Aerotech Motors	Diameter (mm)	Impulse (Ns)	Motor mass (g)	Launch Mass (lb)	Apogee (ft)
L400W	98	4676	5085	52.43	3333
L952W-0	98	5050	5012	52.27	2257
L952W-P	98	5098	5026	52.30	4455
L1120W-P	75	4922	4658	51.49	4603
L1170FJ-P	75	4214	4990	52.22	3560
L1300R-P	98	4556	4884	51.99	3560
L1420R-P	75	4616	4562	51.28	4026
L2200G-P	75	5104	4751	51.70	4974

Using the data obtained above from the simulations, it was determined that the best motor for our rocket was the Aerotech L2200. The thrust curve for this motor is given below. This motor puts the rocket at the closest apogee to the goal of one mile. Using this motor, further simulations were done on the rocket at the anticipated total weight, shown below.

Figure 3.12: Rocket Motor Thrust Curve

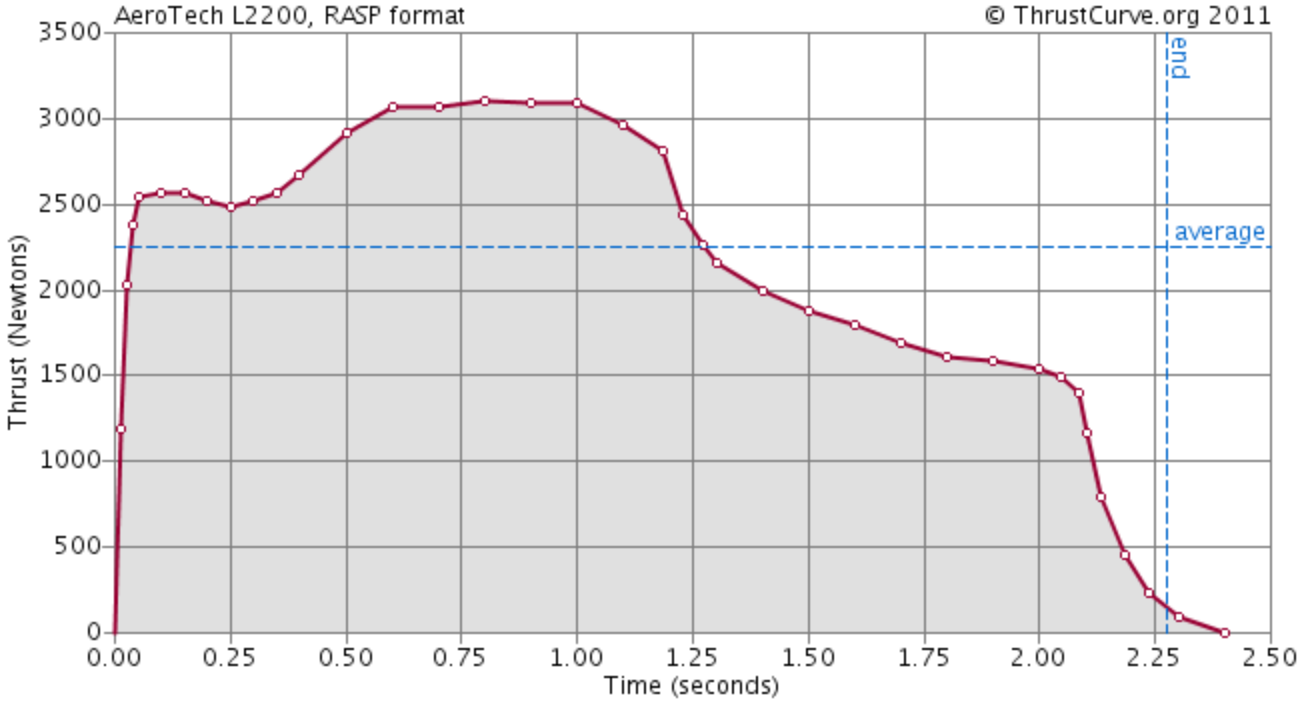
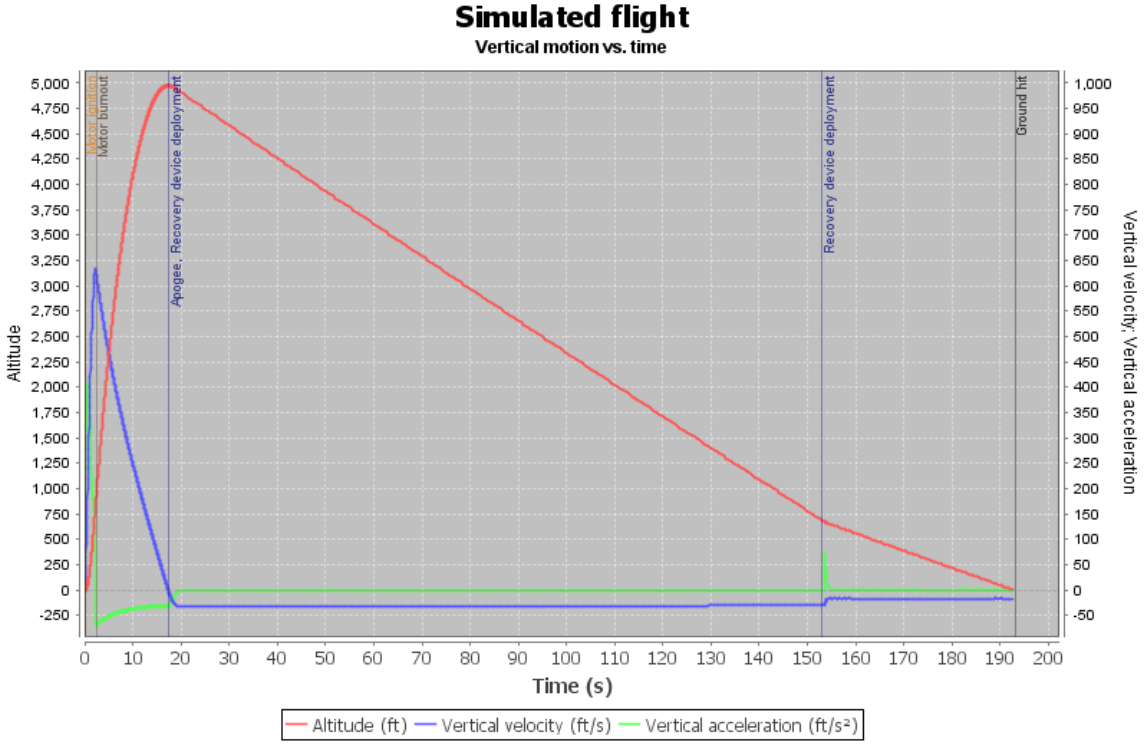


Figure 3.13: Simulated performance with L2200

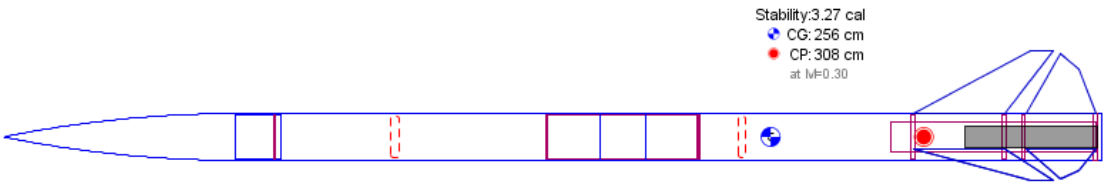


The simulated performance on this motor indicates an apogee of 4974 feet. This apogee is around 6% below the goal of one mile. However, using this same software in previous years has resulted in variations of up to 10% in either direction between predicted and actual apogee. Thus, more data is needed to determine if changes should be made to the

rocket to help meet the altitude goal. This data will be provided by flight testing the rocket. If it is determined that more mass needs to be added, that mass will be added in a location beneficial stability or neutral to it, either above or at the center of gravity. If mass needs to be reduced, a number of options exist, including creating or ordering a plastic nosecone to replace the heavy fiberglass one, or shortening the long and relatively unused upper airframe. Either of these actions could reduce the total mass of the rocket by several pounds, which would be enough to boost the rockets apogee by several percent. If more dramatic action is needed to reach the competition goals, the design will be reassessed and further action taken.

In order to ensure the stability of the rocket, the simulation also takes into account the geometry of the rocket and its mass distribution. Using measurements of weight and size, the simulation software gave the following stability analysis with the specified motor.

Figure 3.14: Rocket simulation and stability information



The given stability margin, the distance between the center of gravity and center of pressure, is 3.27 calibers, or 3.27 times the diameter of the rocket. This over the recommended value of approximately 1.5-2 calibers as a margin of stability. However, current construction expectations are to add more weight to the bottom than the top, which would lower the center of gravity. Additionally, some additional margin of stability at this stage allows for safe removal of mass at a later point, should design changes to increase the apogee prove necessary. Approximately 3 calibers of stability is also safe for performing a test flight, as the expectation with this margin of stability would be slight weathercocking, or some turning into the wind. If the launch day proves especially windy, the launch rod can be angled slightly away from the wind, less than 5 degrees. This has been done for previous projects that have launch on windy days, and helps reduce the effect of any overstability in the rocket. This is only done with the acceptance of the RSO.

3.4 Interfaces and Integration

A. Payload Integration

Due to the complex nature of the UAV payload, special attention must be placed on the problem of integrating it into the rocket airframe. In order to give the UAV adequate flight time, as well as to ensure the UAV is able to safely detach from the rocket, it has been determined that the UAV must be ejected at apogee. If the UAV were to be ejected with the main parachute, it would begin flying at a much lower altitude. It would also have much less time to get RSO confirmation of safety, which would reduce the likelihood that it would be able to fly.

Because the drogue parachute is stored in the booster airframe, the simplest placement for the UAV during ascent is in the same section, directly above the parachute. This way, the ejection charge will pull the UAV out with the drogue parachute. The UAV will be machined to fit nearly snug against the walls of the rocket body, which will reduce any possible vibrations or forces on the UAV. Once it has been deployed and RSO approval has been granted, the team will trigger the release of the UAV, and it will fly autonomously. The UAV will still communicate with the ground through transmission of its GPS coordinates.

The altimeters will be mounted to a payload sled during construction. The payload sled will be designed to fit onto two threaded rods in the coupler section of the rocket. During final assembly, all necessary connections to the altimeters will be made outside the coupler, after which the sled will slide into the coupler. One of the bulkheads will be epoxied to the coupler in order to ensure all components remain in the same location for each launch. The threaded rods will have nuts epoxied onto them at locations to ease installation by making the location of all hardware components the same across flights.

B. Altimeter Integration

In order to ensure safety and decrease complexity, all altimeters will be mounted on a payload sled, which slides onto threaded rods in the coupler. This configuration has been used on previous projects for entire payloads, and it simplifies the construction process and final launch preparations. The altimeter sled will be made of aircraft grade plywood, and will have copper or brass tubing mounted to allow easy mounting to the threaded rods. The sled will also have mounting hardware for the altimeters and holes to allow zip ties to secure the batteries.

3.5 Launch Procedures

A. Launch Platform

All launches of the competition rocket will occur using standard 1515 launch rails 8 feet in height. These are the rails that will be used for the competition flight, and performing multiple launches using the same hardware provides familiarity with the system and safety assurance.

B. Assembly and Launch Procedures

In order to have a safe launch, all team members will undergo pre-flight safety briefings. These briefings will cover safety, procedures, and tasks for all team members, and will take place when the team arrives at the launch field. The contents of the pre-flight briefings will be discussed in detail in Appendix B.

Pre Launch - Day Before:

1. Check that mentor has:
   - Correct motor assembled
   - Correct charge size for each separation event
2. Check that all flight hardware is stored for transportation to launch site

3. Check that all backup equipment and tools are necessary for quick fixes
4. Check that all ground support equipment is packed
5. Check that all team members have read or heard safety briefing and are informed of their responsibilities

Pre Launch - Day Of:

1. Pack equipment for travel
2. Travel to launch location
3. Unpack equipment at launch site
4. Perform preflight checks of UAV and altimeters
5. Assemble avionics bay payload sled, check that all connections are secure
6. Lock altimeter switches in off position
7. Attach e-matches to altimeters
8. Turn on altimeters and check continuity, then turn off altimeters
9. Slide avionics sled into coupler and attach bulkheads
10. Check altimeters are off, and attach ejection charges to terminal blocks
11. Pack drogue parachute
12. Fold UAV for flight, attach to recovery harness, and stow in booster airframe
13. Pack recovery harness and flame protectors in booster airframe
14. Attach coupler and insert shear pins
15. Pack main parachute and flame retardants
16. Attach GPS transmitter to recovery harness
17. Pack recovery harness, attach upper airframe and nosecone, insert shear pins
18. Insert motor into booster airframe
19. Attach motor retainer
20. Bring rocket to RSO for safety inspection
    - Make changes as RSO requires

Launch

1. After RSO approval, wait for range clear
2. When range is clear, move rocket to pad
3. Lower launch rod and mount rocket on the rod
4. Raise rod and rocket to upright position
5. One at a time, arm altimeters; listen for continuity, settings check
6. Check pad power is off and attach igniter to pad controller
7. Insert igniter into motor and plug
8. Leave range and wait for launch
9. Acquire signals from GPS transmitters and UAV before launch
10. Launch rocket
11. At apogee, wait for separation
12. Upon separation confirmation, await RSO approval to detach UAV
13. Upon RSO approval, detach UAV
14. Wait for rocket to land, UAV to complete flight
15. Upon range clear, retrieve rocket and UAV, check for undetonated charges and remove as necessary

16. Return to safe area

Post Launch

1. Remove altimeters from coupler and collect data
2. Collect data from UAV
3. Turn off all avionics and store for transport
4. When travel back is finished, clean all dirty components, remove power sources from avionics, and store all materials for future flights

3.6 Safety and Environment

A. Safety Officer

The safety officer chosen is Jobin Kokkat, a junior in Aerospace Engineering. He has worked on rocket projects with Illinois Space Society for the past two years and has closely observed the previous safety officer. He is aware of the duties and responsibilities required of this position and plans to work closely with the Team Mentor Mark Joseph (NAR 76646 Level 2) to ensure the group's compliance with the NAR Safety Code. In addition to the team mentor, other members of the team are also Level 1 (Jason Allen) and Level 2 (Adam Joseph) certified.

B. Potential Failure Modes

Table 3.5: Rocket Design Failure Modes

Failure Mode	Impact	Mitigations
Bulkhead failure	Damage to payload/UAV, parachutes and onboard electronics. Unstable flight, failed recovery	Proper construction techniques, test to ensure strength.
Fins break/fall off	Unstable vehicle	Use proper construction techniques when attaching the fins, test to ensure strength
Airframe structural damage	Unstable vehicle, rocket does not reach desired altitude, damage to rocket or loss of rocket, mission failure.	Use strong materials for the construction of rocket (fiberglass, epoxy), during construction use proper construction techniques to maintain structural integrity of the rocket
Center of Gravity too far back	Unstable vehicle	Add extra weight to the front of the rocket (nosecone)
Rocket unable to separate	Rocket does not separate and parachutes do not deploy, resulting in high velocity impact with the ground	Properly sanding the connecting sections of the rocket frame to make sure it is not too tight
Rail buttons incorrectly mounted	Rocket breaks free at the beginning of launch. Possible damage to rocket or loss of rocket	Proper design and secure installation of rail buttons

Table 3.6: Payload Integration Failure Modes

Failure Mode	Impact	Mitigation
Unable to signal UAV	Unable to deploy UAV	Test signaling device with UAV inside the rocket. Test at test launch.
UAV unable to deploy	UAV does not perform desired functions	Proper design of deployment method. Ensure that signaling device is working prior to launch. Test to make sure system works
UAV deployment system failure	UAV does not jettison & does not carry out its function	Proper design of deployment method. Ensure that signaling device is working prior to launch. Test to make sure system works. Monitor UAV throughout flight
UAV failure midair	UAV does not perform, UAV freefalls and is damaged and damages whatever it impacts	UAV equipped with parachute to prevent damage in case of failure. Proper testing of UAV and testing at launches to ensure it will not fail and is able to function. Monitor UAV throughout flight
Camera on UAV does not record	UAV does not take video	Make sure UAV is correctly wired. Test cameras over the course of project. Make sure cameras do not turn off mid-flight and check with the manufacturer's guidelines to ensure they will be able to handle the environmental conditions and accelerations
UAV descent rate too high	UAV takes damage upon landing	Equip UAV with a proper size parachute in case it fails mid-air. Properly design and test UAV to ensure that its lift is greater than its weight. Test UAV to ensure it can land efficiently or does not impact ground. Monitor UAV throughout flight
Altimeter not armed or faulty altimeter	Rocket does not separate and parachutes do not deploy, resulting in high velocity impact with the ground	Throughout the project test the altimeter to make sure it works or a replacement can be acquired. Ensure to arm the altimeter on the

		launch pad. Have redundant altimeter in case of sudden failure.
Sled not correct size, rods insecure	Electronics bay unable to fit inside rocket. Electronics bay may become dislodged	Proper design of the sled of the electronics bay and test to ensure secure installation
Key switches hard to access or not securely fastened	Potential difficulty arming altimeters. Wiring may come undone	Properly design an easily accessible location for the key switches and tightly secure key switches. Check throughout project to avoid risky, last minute alterations

Table 3.7: Launch Operations Failure Modes

Failure Mode	Impact	Mitigation
Motor failure	Rocket does not launch/motor launches through rocket	Proper attachment of motor mount, structurally sound motor casing, proper ignition setup
Premature separation	Unstable flight, required apogee not reached, potential recovery failure	Separating sections will be pinned together using nylon shear pins that will break when charges triggered
Charges insufficient	Rocket does not separate and parachutes do not deploy, resulting in high velocity impact with the ground	Sufficient amount of charge testing
Electric match failure	Rocket fails to separate and parachutes do not deploy, resulting in high velocity impact with ground	Backup charges connected to redundant altimeter, inspection of matches prior to installation, sufficient ground tests to give familiarity. Make sure wires connected properly. Team mentor will handle all electric matches
Vehicle explosion midflight	Loss of rocket, mission failure	Proper motor storage, proper construction techniques in regards to motor mount
Propellent explodes	Loss of rocket, mission failure	Proper motor storage, inspect motor components prior to launch
Recovery system failure to deploy	Rocket fails to separate and parachutes fail to deploy, result in high velocity impact with ground	Sufficient amount of charge testing, proper construction techniques,and use of redundant altimeters
Parachute melt/tangle	Parachutes unable to slow down rocket descent resulting in damage	Proper parachute packing, sufficient protection from charges,

	to rocket	sufficient ground testing. The mentor will ensure that the parachute is properly packed
Parachute tear	Parachutes may be unable to slow down rocket descent resulting in damage to rocket	Inspect parachute prior to use. Keep parachute away from sharp objects
Fall too fast/slow	Rocket ends up drifts too far, or damage to rocket	Sufficient parachute size, ground testing to ensure parachute deploys

C. Personnel Hazards

Safety requirements for materials being used (solder, epoxy) are stated in the Material Safety Data Sheets listed on the team's website. These are always available to all team members online and the safety officer and/or the team mentor will be present at all times when any of these materials pose a hazard to anyone. Caution statements will be included in all instructions and plans. All members will adhere to all NAR safety codes, as well as local, state, and federal regulations. Members will be given safety training on equipment to be used in construction of the project prior to handling any of the equipment. For smaller equipment, more experienced team members or the safety officer will provide instructions, while more dangerous equipment training will be handled by personnel with Engineering Special Projects Lab. All new members will only use potentially hazardous equipment under the supervision of experienced members. All personnel are expected to behave properly in the presence of potentially dangerous tools and materials.

All members will be required to wear proper attire whenever construction is taking place such as close toed shoes and non-baggy clothing, and members with long hair must have it tied back. Eyesight must not be impaired by long bangs at any time during construction or when handling potentially dangerous materials. If they interfere with sight at any time, they must be tied back. Proper safety equipment, such as safety goggles, nitrile gloves, and ventilation masks will always be available and must be worn when necessary. Food and drink are not allowed during construction or anywhere near power tools and chemicals.

Table 3.8: Material Hazards

Hazard	Mitigation
Dangerous fumes from chemicals or fiberglass dust	All work with chemicals and dust will take place in well ventilated areas under the supervision of the safety officer or team mentor. Safety goggles and ventilation masks will be used
Skin irritants	Nitrile gloves will be used whenever these materials are handled. The safety officer or team mentor will be supervising any use
Explosive or flammable chemicals	All flammable chemicals will be handled by the team mentor, be stored in appropriate containment units by the mentor and treated appropriately as per the MSDS

Other personnel hazards include proper use of tools and the working environment. For all tools the user manual will be available and the safety officer and experienced members will be supervising.

1. Electric Drill

For construction of the rocket an electric drill will be used to produce holes in predetermined locations on the rocket body. The drill in use is a DeWalt brand drill. The drill is a potentially dangerous tool, if mishandled it may lead to personal injury. Some possible forms of injury are punctures, cuts or electric shocks. These can be mitigated by taking precautions such as:

- Checking the chord for any exposed wire
- Making sure the drill is on safety before plugging it in
- Remove all tripping hazards from the area
- Verifying the drill bit is securely locked inside the drill
- Avoid walking with the drill on
- Wear eye protection
- Make sure what you are drilling is held down
- Learning to properly use the drill
- Store and use away from all liquids

2. Dremel

A Dremel will be used during rocket construction. It is a handheld rotary power tool with many capabilities. It is used primarily for drilling and widening small holes or sanding small portions off the rocket body. Potential forms of injury include punctures, cuts or electric shocks, if it is misused. To prevent injury do the following:

- Checking the chord for any exposed wire
- Making sure the dremel is on off before plugging it in
- Remove all tripping hazards from the area
- Verifying the drill bit is securely locked inside the dremel
- Start with the dremel on low power initially
- Avoid walking with the dremel switched on
- Wear eye protection
- Make sure what you are using the dremel on is held down
- Learning to properly use the dremel
- Store and use away from all liquids

3. Electric Sander

For parts of the rocket construction an electric sander may be used on the rocket body. The sander will be used to ensure that the body of the rocket is smooth and that the couplers will be appropriately separable. The sander is a Bosch brand. Misuse of the sander can lead to potential injuries such as minor burns and electric shocks. This can be mitigated by following these steps:

- Checking the chord for any exposed wire

- Making sure the dremel is on off before plugging it in
- Remove all tripping hazards from the area
- Avoid walking with the sander switched on
- Wear eye protection
- Make sure what you are using the sander on is held down
- Learning to properly use the sander
- Store and use away from all liquids

4. Electric Matches

Electric Matches will be used during the launch operations and charge testing portion of this project. These matches will be used to ignite black powder charges to separate portions of the rocket and deploy parachutes. A burn is a potential injury that can arise from the misuse of an electric match. The team mentor will safely handle and store the electric matches as with all explosive material.

D. Environmental Concerns

Table 3.9: Potential environmental concerns due to the vehicle

Concerns	Mitigation
Potential fire due to charge testing	All testing will be done outdoors in a clear area far from property and flammable objects
Risk of fire from flammable substances	All flammable objects will be handled with caution and be stored in a secure location as per the MSDS. All explosive material will be handled and safely stored by the team mentor
Risk of fire from rocket launch	The rocket will be launched above the ground and flammable materials will be removed from the proximity of the launch pad. All explosive material will be handled and safely stored by the team mentor
Improper disposal of chemicals or waste	All hazardous material including epoxy, black powder and rocket motor will be properly disposed of as stated in their MSDS. The mentor will carry out the disposal of all explosive material

E. Preflight Briefing

The safety officer will conduct a preflight briefing for all team members prior to assembly of the rocket on launch day. During this briefing the safety officer will:

1. Go over all safety rules with team members
2. Emphasize people being cautious while working
3. Go through the launch day procedure (detailed elsewhere in report) to ensure all members understand what needs to be done
4. Assign specific duties to all team members so that all necessary tasks are completed in a quick, safe, and efficient manner, under the supervision of the team mentor and safety officer

4. Payload Criteria

A. Mission Statement

The main objective of the engineering payload is to launch an Unmanned Aerial Vehicle quadrotor aircraft to fly autonomously after being ejected from the rocket at apogee. The UAV must record video during flight, fly autonomously for a short period, and be successfully recovered.

B. Requirements

In order to successfully complete the mission, the payload must follow the engineering goals set by the team as well as the competition guidelines specified by NASA. These requirements include:

1. The UAV will be foldable to allow integration into the rocket
2. The UAV will be attached to the shock cord and remain attached until given permission by RSO to deploy
3. The UAV detachment mechanism will be controlled entirely from the ground and will be initiated by the team
4. Upon deployment, the UAV will unfold its arms and lock into flight configuration and deploy a parachute which will allow the stabilization algorithm to begin running
5. The UAV will then fly autonomously, following a predetermined algorithm and flight plan
6. The UAV will be able to record video during flight
7. The UAV will have one full scale test flight, during which it functions as planned for the competition

C. Mission Success Criteria

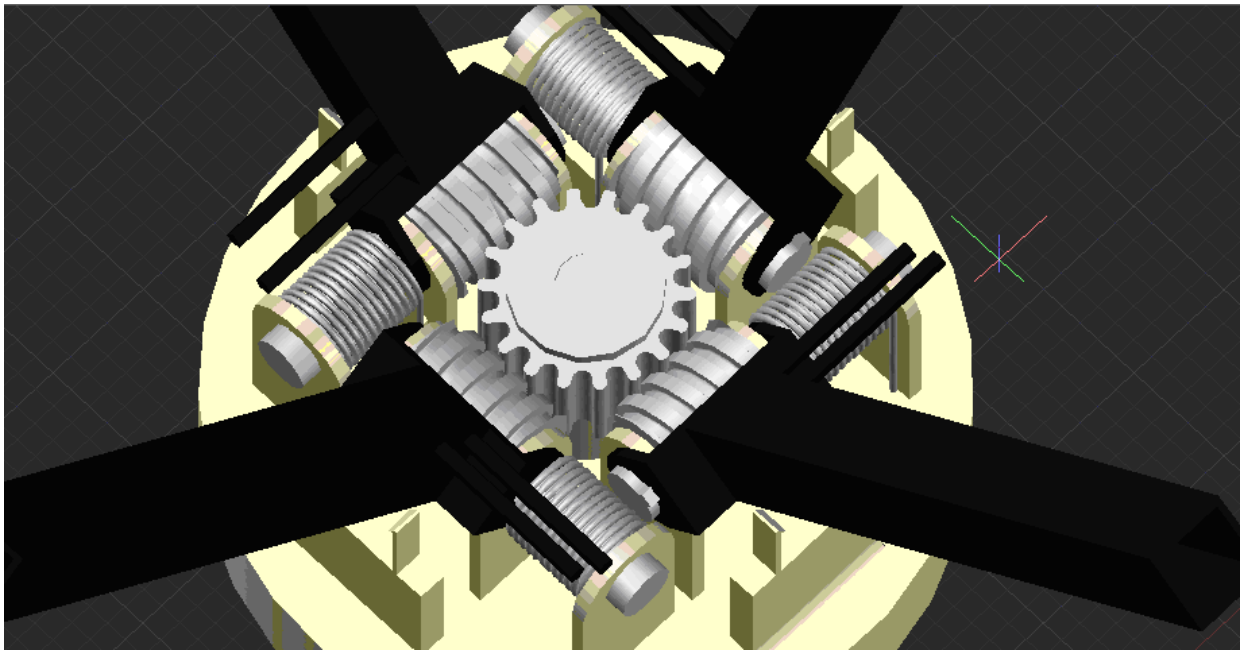
The UAV payload will be successful upon safe completion of all competition requirements, and its engineering payload is collected and retrieved by the team.

4.1 Payload Design and Analysis

A. Design overview

As mentioned in our proposal, the quadrotor we designed is comprised of four foldable arms linked together by a worm gear mechanism which guarantees equal unfolding of all of these arms. The four outer worms, as show below, are each connected to a quadrotor arm via keyed shafts, and are all connected to the central worm gear; guaranteeing the simultaneous motion of all four arms. All four of the arms have a 360 degree torsion spring installed on one side of the shaft (as seen above), which will provide enough torque to help the arms expand once deployed.

Figure 4.1: UAV arm attachments



A charge released locking mechanism designed by Defy Gravity (shown below) will be attached to a notch in the side of the base which will allow the UAV payload to separate from the rocket upon confirmation from the ground station. The reliability of this device has been tested but will continue to be tested once that step of the design process is achieved.

Figure 4.2: Defy Gravity Tether

First we must focus on the guaranteed deployment of all four arms and then we will proceed to integrate it with the rocket. Additionally, a location for the shock cord to pass behind the UAV to attach to the eyebolt attached to the motor case will be made in the base of the UAV. As mentioned in our revisions, we will also be replacing machined components with 3D printed parts. The cost and weight of the parts we need to machine will be a lot lower and upon further stress tests completed by the manager of the Rapid Prototyping Lab at UIUC, we will decide whether or not we would like to continue in this

direction. The UAV base would be the only component of the UAV that would be 3-D printed. All other structural components would be purchased from McMaster Carr. A schematic of the base is shown below.

Figure 4.3: UAV Base

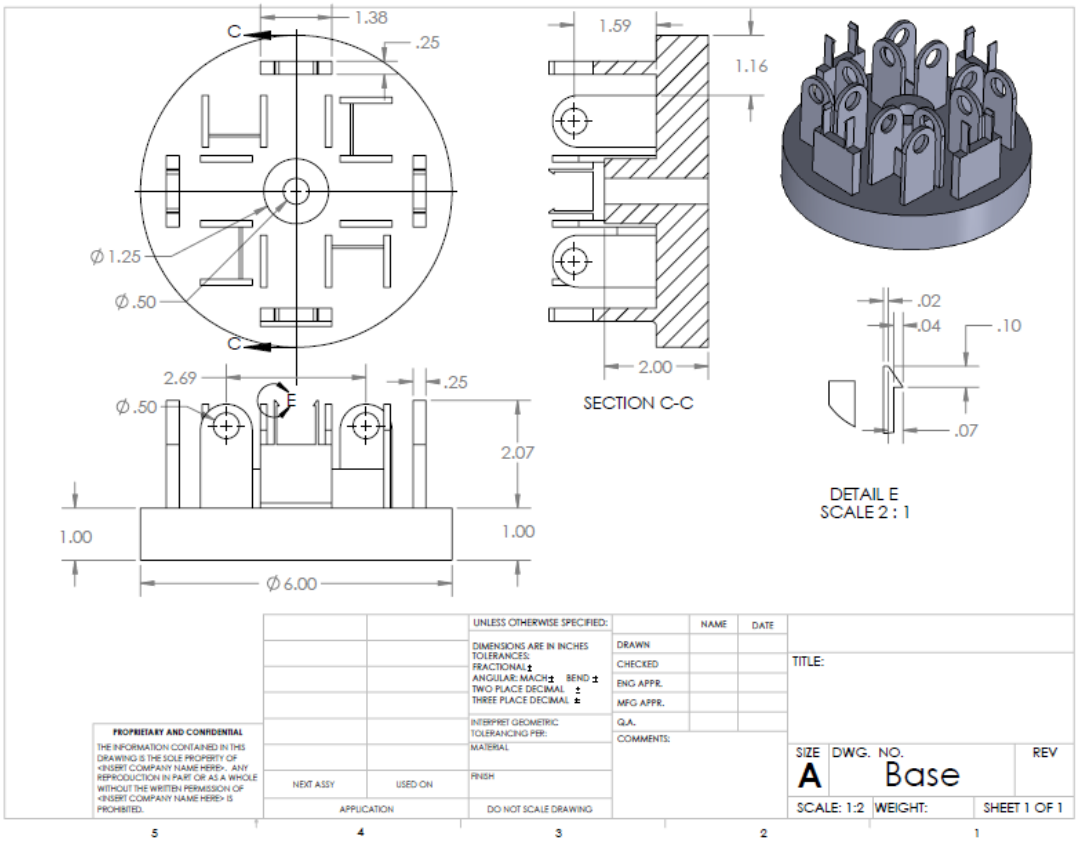
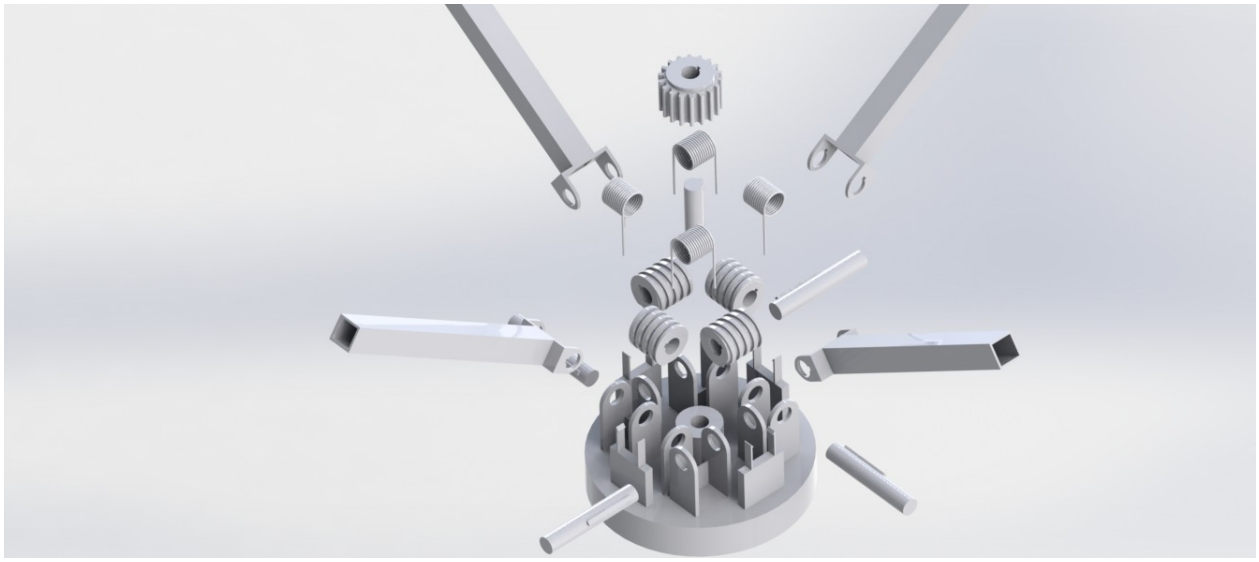


Figure 4.4: Exploded Assembly



The control system of the UAV will encompass a major portion of the payload goals. Many options are available to design a control law for the quadrotor. Choices can range from a simple classical control approach based on a PID design, a modern linear quadratic (LQ) method, a nonlinear approach, or a combination of these choices. Due to the guaranteed stability and robustness properties, this project focuses on the LQ approach to the control problem. Specifically the explicit model following LQR method was researched and will be implemented.

The dynamic equations describing the quadrotor motion are the same for all quadrotors. However, this project was conducted in regards to a specific flight vehicle that we designed; therefore we have to find the parameters associated with this vehicle. Once these parameters are defined, we will proceed to adjust the Q and R matrices of the performance index which will give us an optimal solution to the controls of the quadrotor. Below are the 6 nonlinear coupled differential equations of motions we will be linearizing for our controls.

Figure 4.5: Control equations

$$\begin{cases} \ddot{x} = (\cos\psi \sin\theta \cos\phi + \sin\psi \sin\phi) U_1 / m \\ \ddot{y} = (\sin\psi \sin\phi \cos\phi - \cos\psi \sin\phi) U_1 / m \\ \ddot{z} = (\cos\phi \cos\theta) U_1 / m - g \\ \ddot{\phi} = \left[l U_2 + \dot{\theta}\dot{\psi}(I_y - I_z) \right] / I_x \\ \ddot{\theta} = \left[l U_3 + \dot{\phi}\dot{\psi}(I_z - I_x) \right] / I_y \\ \ddot{\psi} = \left[U_4 + \dot{\phi}\dot{\theta}(I_x - I_y) \right] / I_z \end{cases}$$

Once the control systems have been determined through analysis and verified through testing, the final control algorithm will be implemented on the main computer of the UAV,

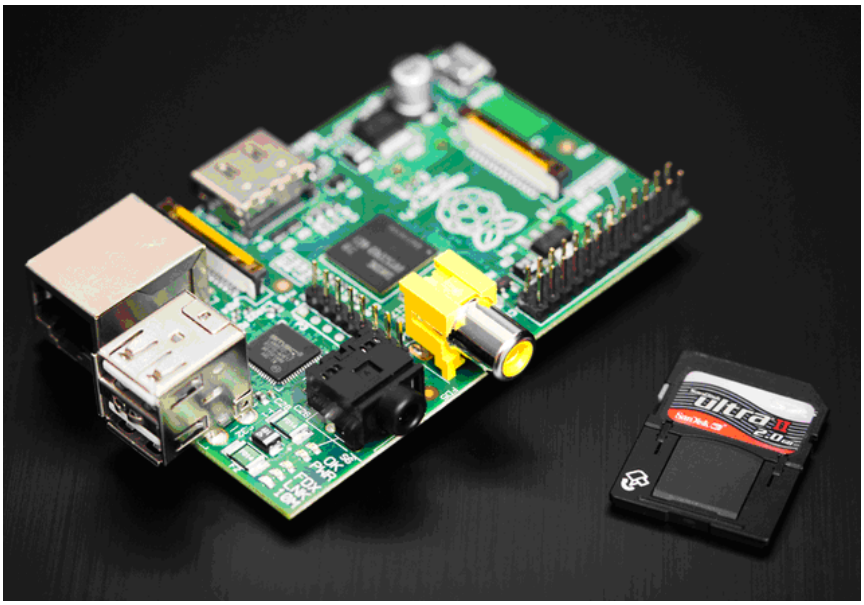
the Raspberry Pi computer, which will be able to fly the UAV autonomously.

B. Flight Hardware

Raspberry Pi:

The Raspberry Pi is a credit-card sized computer that plugs into your TV and a keyboard. It is basically ARM Linux PC which can be used for many of the things that your desktop PC does. We will be using the Raspberry Pi as the central controller for the quadrotor. All processing will be done onboard in real time using C as our development language and it will communicate with various other hardware components such as Parallax Propeller chip over either USB or UART.

Figure 4.6: Raspberry Pi Computer



Parallax Propeller:

The parallax propeller chip contains eight processors (cogs) that can operate simultaneously, either independently or cooperatively, sharing common resources through a central hub. Operating at speeds up to 80MHz per cog, the propeller is the ideal solution for our UAV. All sensor readings will be taken with the Propeller and communicated over UART to the Raspberry Pi. The motors will also be controlled with the Propeller since it has an excess of input output ports which are capable of a wide variety of things.

Great Planes Silver Series 35A Brushless ESC 5V/2A BEC

These ESC's are great for delivering 35A of continuous current with a built-in Battery Eliminator Circuit which can handle 2A, this ESC is very simple to use with a safety arming procedure implemented. High refresh rate and thermal protection gives us further reassurance with this product.

Great Planes Rimfire 400 Outrunner Brushless Motor

Excellent motors designed for explosive acceleration and maximum torque. Lightened aluminum can houses high torque rare earth Neodymium magnets. These motors are virtually maintenance free.

X-Bee 900 Pro Transceiver
The X-Bee 900 Pro Transceiver is responsible for providing communication between the UAV and our ground station. The X-Bee will transmit data such as GPS tracking information and sensor measurement information. The X-Bee will communicate over UART to the Parallax Propeller.

UM6 Ultra-Miniature Orientation sensor
This sensor from Pololu uses rate gyros, accelerometers, magnetic sensors, and an onboard 32-bit ARM Cortex processor to estimate the absolute sensor orientation 1000 times per second. The resolution on this sensor is 0.01 degrees and can be coupled with our parallax GPS module to provide position, altitude, speed, and course outputs.

RXM-SG GPS Module w/ Ext Antenna
The RXM-SG GPS Module provides a high quality, highly sensitive GPS receiver with an external antenna to provide a complete GPS solution for both microcontroller and PC applications. Testing for reliability in measurements have been done and the GPS chip was able to capture ample amounts of satellites for position tracking. Raw NMEA0183 data will be transmitted to the UM6 Ultra-Miniature Orientation sensor for further processing.

Flightpower Pro50 2550 mAh 4S 11.1V Li-Po battery
This is a very powerful and lightweight battery that will be able to discharge enormous current providing massive power for all 4 brushless motors (1 battery per 2 motors).
All of the components above will be mounted to the bottom of the base shown previously aside from the UM6 IMU which will need to be positioned at the center of rotation of the quadrotor.

C. Verification Plan

Table 4.1: The payload verification plan is still in the early stages of development.

Requirement	Verification	Implementation
The quadrotors arms will unfold smoothly and lock into place once released from the rocket.	3D printing Stress Test Analysis	Test, Inspection
The UAV payload will hover and continue to be stable even with external disturbances	Controls	Test
Kalman Filter is tuned and IMU is	Programming	Test

calibrated		
The UAV will read all sensors values at a sufficient rate and perform data analysis to filter good/bad signals	Programming	Test

4.2 Payload Concept

The payload onboard the rocket will consist of a UAV which has the capability to hover autonomously and hold a GPS position once deployed. Real time data will be collected onboard the UAV and a select amount of information will be streamed to our designated ground control station. There we can consistently monitor its activity in an effort to prevent a safety hazard to the spectators below. Some of the data collected will include altitude, temperature, barometric pressure, and panoramic video feed. Sophisticated hardware for this mission will be employed and will allow all mission critical processing to be done onboard the UAV. Complex topics in controls and fine tuned programming algorithms will be used to guarantee the success of this mission.

Unmanned aerial vehicles have received a lot of interest and attention in recent years. Their ability to perform tasks considered monotonous or dangerous at a low cost makes them excellent platforms for experiments in research institutions and engineering companies. Small UAVs such as the quadrotor are excellent for indoor testing, relatively cheap, and provide students with the ability to understand all aspects of its flight from the mechanical design to controls. The payload we are pursuing this year is going to be a very complex undertaking to say the least and encompasses a wide variety of disciplines in order to guarantee its success. The long term goal of this project is to develop a stable rocket deployed UAV platform capable of taking precise measurements and maneuvering at high altitudes with little to no human input. We have split up the project into three large components, mechanical, controls, and electrical/programming.

4.3 Science Value

A. Payload Objectives

The objective of the payload is to be able to maintain a stable hover at high altitudes and navigate to GPS coordinates based off of our control algorithms, ALL autonomously. In order for this mission to be successful we need to design a system that can work efficiently with simplicity in mind. The fewer factors we have to worry about during flight, the better. Therefore the mechanical design along with the electrical hardware implantation is as simple as can be for a system of this complexity. We will approach each step of the process individually and address issues immediately after they arise. This will limit the chance of error we will encounter during actual flight.

B. Success Criteria

The payload will be considered successful if the following requirements are met, while maintaining the safety of the team and all those observing the launch:

1. The UAV successfully ejects from the rocket at apogee
2. The UAV detaches from the recovery harness upon receiving a command from the ground, initiated after RSO approval
3. The UAV successfully deploys from ascent configuration to flight configuration
4. The UAV successfully attains level flight after being ejected
5. The UAV collects locational data from GPS transmitter and relays it to the ground
6. The UAV successfully captures video during its flight
7. The UAV, upon finishing its flight, successfully descends and lands softly

C. Experiment Procedure and Processes

1. UAV Testing

The following is the intended sequence of testing to be done for the integration of the UAV payload system. After each test is completed necessary adjustments will be made to optimize the performance of the UAV. Once all tests are completed the UAV will be prepared for the final launch.

A series of static tests will be performed to make sure various aspects of the constructed UAV function as designed. Static testing will make sure the rocket integrates properly physically into the rocket, and attaches as appropriate to the recovery harness. Static testing will also confirm that the rocket does not interfere with recovery electronics, and will be used to verify the transmission of GPS data before flight.

A flight test from the ground will be performed to determine whether the UAV flies correctly and establishing that the designed controls work as intended. The vehicle will take off from a flight configuration at rest while on the ground, and will perform a short flight before landing. Another possible flight test of the UAV would be an endurance flight, to test how long the vehicle may remain airborne.

Separate tests of individual components of the tether system will then be performed to confirm that the remote control aspect is functional and able to deploy the foldable arms of the UAV when given the signal. The tether's release mechanism will be validated on the ground before a flight test is attempted.

A fully integrated charge test with UAV will determine whether the UAV can survive the deployment process and can function afterwards. This will be the first full system test of the entire rocket and payload, as it will include all flight components of both systems. The test will provide data on whether any changes to deployment procedures need to be changed, and will help ensure the safety of the deployment process for the full flight test.

A drop test will then be conducted to check that the UAV can unfold its arms and then proceed to fly and correct its position all while falling in mid-air. If a building can be found that is tall enough to allow the UAV to unfold and stabilize before it hits the ground, the UAV will be dropped while still in its stored configuration and given orders to deploy and stabilize its flight. This test will validate that the UAV can deploy after being released from the rocket.

The final test of the UAV will be the full scale test launch, where the rocket will perform all aspects of its flight as expected for the final competition flight. All other tests perform validation of safety and design of one or more components of the system, while the full scale launch test serves as a validation of the entire system prior to the competition.

4.4 Safety and Environment

A. Safety Officer

The safety officer chosen is Jobin Kokkat, a junior in Aerospace Engineering. He has worked on rocket projects with Illinois Space Society for the past two years and has closely observed the previous safety officer. He is aware of the duties and responsibilities required of this position and plans to work closely with the Team Mentor Mark Joseph (NAR 76646 Level 2) to ensure the group's compliance with the NAR Safety Code. In addition to the team mentor, other members of the team are also Level 1 (Jason Allen) and Level 2 (Adam Joseph) certified.

B. Potential Failure Modes

Table 4.2: Payload Design Failure

Failure Mode	Impact	Mitigation
UAV unable to handle the accelerations or environmental conditions	Damage to UAV, inability of UAV to perform, mid-air UAV failure	Use of strong materials when constructing the body of the UAV. For electronic components check with manufacturer to ensure they will remain functional. Properly secure all electronic components. Systems check before UAV released from rocket to ensure systems are functioning to prevent accidental mid-air failure. Test UAV during test launch.
UAV does not fit in rocket	Unable to fly in rocket	Proper considerations taken during design of the UAV. Ensure arms fold correctly
Camera on UAV does not record	UAV does not take video	Make sure UAV is correctly wired. Test cameras over the course of project. Make sure cameras do not turn off mid-flight and check with the manufacturer's guidelines to ensure they will be able to handle the environmental conditions and accelerations

Onboard electronics unable to handle the accelerations or environmental conditions	Recovery system failure, critical damage to rocket	Check with manufacturer to ensure electronic components will remain functional. Properly secure all electronic components. Test during the test launch

Table 4.3: Payload Integration

Failure Modes	Impact	Mitigation
Unable to signal UAV	Unable to deploy UAV	Test signaling device with UAV inside the rocket. Test at test launch
UAV unable to deploy	UAV does not perform desired functions	Proper design of deployment method. Ensure that signaling device is working prior to launch. Test to make sure system works
UAV deployment system failure	UAV does not jettison and does not carry out its function	Proper design of deployment method. Ensure that signaling device is working prior to launch. Test to make sure system works
Poor wire connection	Unable to signal UAV deployment, altimeters do not work, charges do not deploy	Properly plan when connections will go during design and use reliable wiring and proper installation methods. Double check connections prior to launch
Sled not correct size, rods insecure	Electronics bay unable to fit inside rocket. Electronics bay may become dislodged	Proper design of the sled of the electronics bay and test to ensure secure installation

Table 4.4: Launch Operations Failure Modes

Failure Modes	Impact	Mitigation
UAV failure midair	UAV does not perform, UAV freefalls and is damaged and damages whatever it impacts	UAV equipped with parachute to prevent damage in case of failure. Proper testing of UAV and testing at launches to ensure it will not fail and is able to function. Ensure that the battery power supply is securely fastened. Monitor UAV throughout flight
Electric match failure	Rocket fails to separate and parachutes do not deploy, resulting in high vel impact with ground	Backup charges connected to redundant altimeter, inspection of matches prior to installation, sufficient ground tests to give familiarity. Make sure wires connected properly
Altimeter not armed or faulty altimeter	Rocket does not separate and parachutes do not deploy, resulting in high velocity impact with the ground	Throughout the project test the altimeter to make sure it works or a replacement can be acquired. Ensure to arm the altimeter on the

		launch pad. Have redundant altimeter in case of sudden failure
UAV descent rate too high	UAV takes damage upon landing	Equip UAV with a proper size parachute in case it fails mid-air. Properly design and test UAV to ensure that its lift is greater than its weight. Test UAV to ensure it can land efficiently or does not impact ground. Monitor UAV throughout flight

C. Personnel Hazards

Safety requirements for materials being used (solder, epoxy) are stated in the Material Safety Data Sheets listed on the team's website. These are always available to all team members online and the safety officer and/or the team mentor will be present at all times when any of these materials pose a hazard to anyone. Caution statements will be included in all instructions and plans. All members will adhere to all NAR safety codes, as well as local, state, and federal regulations. Members will be given safety training on equipment to be used in construction of the project prior to handling any of the equipment. For smaller equipment, more experienced team members or the safety officer will provide instructions, while more dangerous equipment training will be handled by personnel with Engineering Special Projects Lab. All new members will only use potentially hazardous equipment under the supervision of experienced members. All personnel are expected to behave properly in the presence of potentially dangerous tools and materials.

All members will be required to wear proper attire whenever construction is taking place such as close toed shoes, and non-baggy clothing, and members with long hair must have it tied back. Eyesight must not be impaired by long bangs at any time during construction or when handling potentially dangerous materials and must be tied back. Proper safety equipment, such as safety goggles, nitrile gloves, and ventilation masks will always be available and must be worn when necessary. Food and drink are not allowed during construction or anywhere near power tools and chemicals.

Table 4.5: Material Hazards

Hazard	Mitigation
Dangerous fumes from chemicals and dust	All work with chemicals and dust will take place in well ventilated areas under the supervision of the safety officer or team mentor. Safety goggles and ventilation masks will be used
Skin irritants	Nitrile gloves will be used whenever these materials are handled. The safety officer or team mentor will be supervising any use
Burns from soldering	Proper soldering techniques, use of proper safety equipment

Other personnel hazards include proper use of tools and the working environment. For all tools the user manual will be available and the safety officer and experienced members will be supervising.

1. Solder Gun

The soldering gun will be used in the physical construction of the electronics for the payload. It is used to connect circuitry and electronic hardware. The solder gun heats up a metal tip which is then pressed over solder, which is then liquefied and used to make electrical connections. Since the tip gets very hot burns are a potential injury that can result from improper use of this tool. All users will receive training prior before use of this tool. To help prevent injury do the following:

- Checking the chord for any exposed wire
- Making sure the solder gun is set down before plugging it in
- Remove all tripping hazards from the area
- Avoid physically handing others the solder gun
- Avoid walking with the solder gun on
- Wear eye protection and skin protection, including close-toed shoes
- Learning to properly use the solder gun before use
- Store and use away from all liquids

2. Electric Drill

For construction of the rocket an electric drill will be used to produce holes in predetermined locations on the rocket body. The drill in use is a DeWalt brand drill. The drill is a potentially dangerous tool, if mishandled it may lead to personal injury. Some possible forms of injury are punctures, cuts or electric shocks. These can be mitigated by taking precautions such as:

- Checking the chord for any exposed wire
- Making sure the drill is on safety before plugging it in
- Remove all tripping hazards from the area
- Verifying the drill bit is securely locked inside the drill
- Avoid walking with the drill on
- Wear eye protection
- Make sure what you are drilling is held down
- Learning to properly use the drill
- Store and use away from all liquids

D. Environmental Concerns

Table 4.6: Potential environmental concerns due to the payload

Concerns	Mitigation
Potential fire due to charge testing	All testing will be done outdoors in a clear area far from property and flammable objects
Risk of fire from flammable substances	All flammable objects will be handled with caution

	and be stored in a secure location as per the MSDS. All explosive material will be handled and safely stored by the team mentor
Risk of fire from rocket launch	The rocket will be launched above the ground and flammable materials will be removed from the proximity of the launch pad. All explosive material will be handled and safely stored by the team mentor
Improper disposal of epoxy or solder	All hazardous material including epoxy and solder will be properly disposed of as stated in their MSDS. The mentor and the safety officer will supervise and ensure the safe disposal of all materials

5. Project Plan

5.1 Budget

The budget for this project is tabulated below as currently stands. Items in any table marked with an asterisk "*" are items taken from completed projects in previous years, and as such are not adding to the total cost of the budget. They are included here to demonstrate that the team can complete the requirement that the total cost of the competition rocket will not exceed $5000 on the pad. The amounts reflected in the total budget are items that will be ordered on this year's budget.

Table 5.1: Total Project Budget

Subsystem/Group	Total Cost
Rocket (Structure)	1505.83
UAV (Payload)	521.42
Educational Outreach	200
Travel	2550
Total	4777.25

The projected total budget has decreased significantly since the proposal. The majority of this decrease comes through the changes to the payload, specifically the removal of the SMD science goal. The instruments necessary to complete this payload would have required significantly larger budgets. Additional savings came from careful inventory of items already in the tech teams possession, mostly from previous projects. These items, especially the rocket body and altimeters, further significantly reduce the overall cost of the project, as can be seen below.

Table 5.2: Rocket Budget

Item	Quantity	Unit Cost	Item Total Cost	Received (Y/N)
Ultimate Darkstar Kit *	1	679	679	Y
Proline 4100 Epoxy *	1	119.99	119.99	Y
Motor Retainer Assembly	1	52	52	Y
Motor Adapter Assembly	1	45	45	N
Motor Casing	1	573.99	573.99	N
Stratologger Altimeter *	2	79.95	159.90	Y
Telemetrum Altimeter *	1	350	350	Y
Beeline Transmitter	1	115	115	N
Colloidal Silica Filler *	1	24.99	24.99	Y

Rail Buttons	2	4.43	8.86	Y
Connecting Hardware *	1	50	50	Y
Shock Cord	40 yards	2.10	84	N
Main Parachute	1	170	170	N
Drogue Parachute*	1	45	45	N
Parachute Protector *	2	3.29	6.58	N
Altimeter Switches *	3	2.50	7.50	Y
Black Powder *	1	23.55	23.55	Y
e-matches *	1	32	32	Y
Igniters *	1	5.95	5.95	Y
Subscale Rocket	1	65.00	65.00	N
Motor reloads	2	190.99	381.98	N
Total			2955.86	
Total minus previously owned components			1505.83	

Table 5.3: UAV Budget

Item	Quantity	Unit Cost	Item Total Cost	Received
Lipo Battery	2	67.99	135.98	N
Push Props	6	1.89	11.34	N
Tractor Props	6	3.39	20.34	N
Xbee USB Adapter	1	23.99	23.99	N
Worm Gear	1	57.99	57.99	N
Worms	4	28.10	112.40	N
Torsion Springs	8	2.99	23.92	N
Axle Keyed Drive Shaft	1	21.70	21.70	N
Standard Key Stock	2	2.07	4.14	N
Shaft Collars	8	0.84	1.68	N
XBee SIP Adapter	1	27.99	27.99	N
Tether	1	79.95	79.95	N
Raspberry Pi *	1	25	25	Y
UM6 Pololu IMU *	1	199.00	199.00	Y
Rimfire Brushless *	4	49.99	199.96	Y
Great Planes ESC *	4	39.99	159.96	Y
RXM-SG GPS *	1	79.99	79.99	Y

Propeller Chip *	1	7.99	7.99	Y
Prop Plug *	1	14.99	14.99	Y
XBee Pro 60mW *	2	36.99	73.98	Y
Total			1282.29	
Total minus previously owned components			521.42	

The travel costs given below are approximations from previous travel by the ISS Tech Team, and account for increases in travel costs since previous trip arrangements.

Table 5.4: Travel Costs

Expense	Number	Cost Per	Total
Transportation Vehicle	3	250	750
Gas	3	200	600
Lodging	3	400	1200
Total			2550

5.2 Funding

Funding sources have been sought throughout the duration of the project to help ensure the project is fully funded. The funding sources presented below represent both current levels of funding and anticipated funding, depending on the source. The funding levels as anticipated are adequate to cover all competition costs. If additional funds are determined to be necessary, the ISS Tech Team can work with other groups in the Illinois Space Society to acquire funding, and may also pursue fundraising activities on campus as needed.

Table 5.5: Funding Sources

Funding Source	Estimated Funding	Received
UIUC Design Council Funding	$2500	Y
Illinois Space Society Funding	$700	Y
SORF Contribution	$1700	N

5.3 Project Timeline

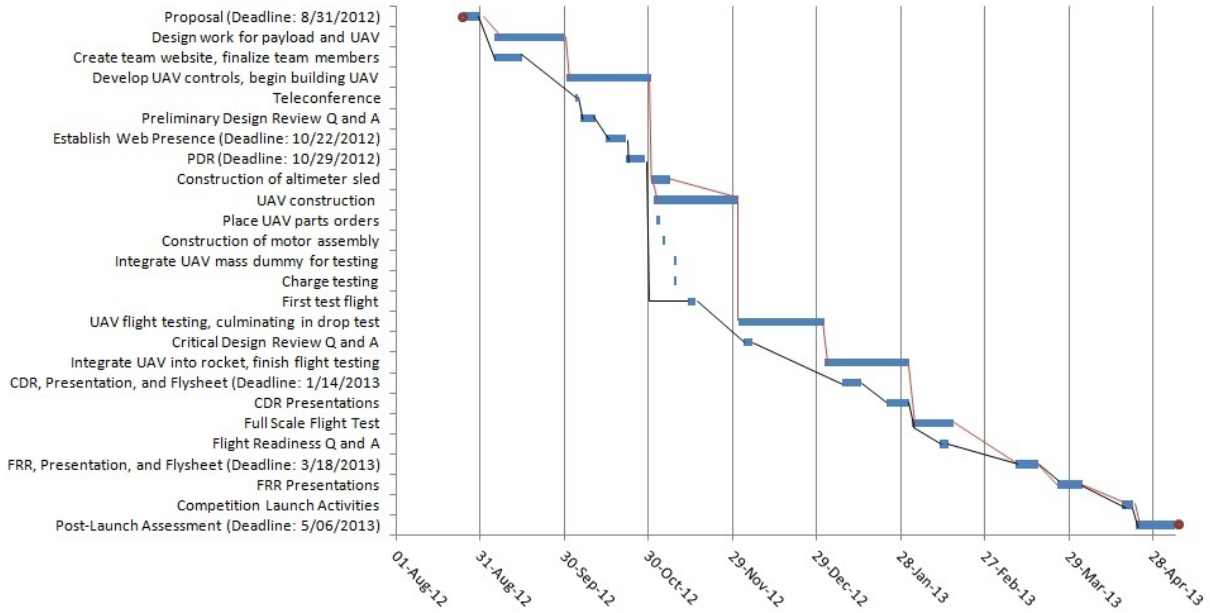
The project timeline listed below includes all events that have set dates, and anticipated dates for future events.

Table 5.5: Milestone Timeline

Date	Milestone
Aug 31	Proposal Due
Mid Sep	Create team website, finalize team members

Sep 27	Selection Notification
End of Sep	Finish design work on payload and UAV
Oct	Develop UAV controls, begin building UAV
Oct 4	Teleconference
Oct 11	Preliminary Design Review Q and A
Oct 22	Establish Web Presence Deadline
Oct 29	**PDR Due**
Oct 31	Finish UAV design
End of Oct	Finish fin assembly construction
Oct 31	Begin construction of altimeter sled
Nov-Dec	UAV construction period
Nov 2	Place UAV parts orders
Nov 5	Finish motor assembly
Nov 6	Finish altimeter sled
Nov 8	Integrate UAV mass dummy for testing
Nov 9	Complete charge testing
Nov 13	PDR Presentation
Mid November	Complete first test flight
Nov 12-23	Develop UAV controls systems
Dec 3	Critical Design Review Q and A
Dec 7	Finish UAV construction
Dec 7-20	UAV flight testing, culminating in drop test
Jan	Integrate UAV into rocket, finish flight testing
Jan 14	CDR, Presentation, and Flysheet Due
Jan 23 - Feb 1	CDR Presentations
Feb 11	Flight Readiness Review Q and A
Feb	Full Scale Flight Test
Mar 18	FRR, Presentation, and Flysheet Due
Mar 25 - Apr 3	FRR Presentations
Apr 17 - 21	Competition Launch Activities
May 6	Post-Launch Assessment Review Due

Figure 5.6:Project Timeline Gantt Chart



The red path shows how the building activities lead up to the final presentation, launch day, and the post launch assessment. This represents a very critical path of the project , as they all must be completed to meet the mission success criteria. The path can be seen to split into two paths due to the multitasking done by the different functional groups of the entire ISS Tech Team. While the other events not connect by the red path are important, the connected events represent the ones that are the most labor and time intensive. The black path represents critical deadlines that must be met for the project. The red path connects with the black path at the end of the project to show how the critical building path will meet the deadlines through the use of careful planning, multitasking of the team and the distribution of workload to the different functional groups.

5.4 Educational Outreach

A. Goals

The focus of the ISS Tech Team's educational outreach plan are to reach as many students as possible, promote interest in rocketry primarily in younger students, and to inspire students about what they can achieve now as well as in the future. To accomplish this, team members will make frequent visits to nearby schools bringing with them presentations pertaining to rocketry and payload-related topics for students to experience; additionally, our team will engage students outside of the classroom at several other events throughout the year. At these events, demonstrations of our team's findings will be conducted and supplemented by smaller scale projects in which the students can interact with materials

that will allow them to take in a rocketry-based experience.

In order to receive feedback on and to improve our future outreach opportunities, feedback forms will be requested from students who participate in our outreach initiatives and the teachers who supervise them. These feedback forms will request insight regarding the information learned from the outing, the clarity of the presentation, and the fluidity of the projects completed. Our team will then analyze the information gathered from these forms and compare it to our desired outcomes, in terms of concepts successfully conveyed and deliverables produced. From this, we will have a much more clear understanding of how to better serve our community in future endeavors.

B. Outreach Logistics

The ISS Tech Team has numerous opportunities to engage in educational outreach throughout the year. The most prominent of these being those in which we can engage students in the classroom and provide them with information about rocketry and science in general. During these engagements, ISS Tech Team members will present a short introduction to rocketry along with descriptions of their experiences with rocketry, this, and other projects. The team will also engage students with hands on demonstrations and projects so that they will have an immediately understanding of how satisfying rocketry can be.

Possibilities for these projects include dividing students up into teams and having each team create a small Estes rocket; this allows the students to express their ideas on rocketry and its design processes while simultaneously engaging directly with the material. Each team will then get the chance to launch their rocket, under our supervision, and measure their success. This project will be aimed exclusively at younger students – grades K-5th. When presenting to older students, grades 6th-12th, our team will include information pertaining to avionics equipment and also cover the more advanced aspects of our UAV payload. All aspects of our educational outreach will be organized by our educational outreach team lead who will be in charge of determining specific local schools and classes to visit, as well as developing a list of materials to be presented. This team member will also decide on the hands on experience, as detailed above, that is most applicable, engaging, and safe for each outreach event.

C. Status

Currently, our Tech Team is signed up to present at Mahomet Science Day, a day dedicated to displaying several scientific aspects to the students who attend one of the three schools in the Mahomet, Illinois area. This event will take place on the Friday of November 9th and we intend to present to 3rd-5th graders with a focus on the structural

aspect of our rocket. In addition, our team has opportunities to present at Booker T. Washington STEM Academy as well as Thomas Paine Elementary right here in Urbana, IL. The presentations at these locations will be given to six different classrooms of approximately 30-35 students per class which allows us to present our materials to a large group of students of varying age groups. This serves to ensure that our presentations will be widely varied and effective for each group of students.

In addition to reaching out to local students in the classroom, ISS Tech Team has the opportunity to present at on-campus events such as Engineering Open House (abbreviated EOH herein). At EOH, the team will present the rocket and payload to the general public, consisting of 20000+ students and their families from Illinois as well as surrounding states, to promote interest in rocketry on a general scale and NASA SLP in particular. Typically, these projects will be viewed by people of differing backgrounds and experiences which serve to enhance our presentations further through interaction with them. Team members will make presentations to large groups of spectators, as well as answer questions and discuss projects with individuals; feedback will be plentiful from this event.

Our outreach endeavors will conclude with an event of our very own organization: Illinois Space Day. Illinois Space Day, hosted for the first time just one year ago, is an event that brings down a substantial amount of students and their families, attendance was over 200 in the previous year, to the University of Illinois for a thorough look at all things related to space and the space sciences. Our Tech Team featured a thorough exhibit at this event last year and we will be holding another presentation this coming April [the event will take place on April 14th, 2013]. With the date of the event being so late in the year, our project will be in its final stages of work which allows us to present the most materials on it to the audience of students and adults who attend. Students will have the chance to engage with our work hands-on and watch recordings of our testing and construction of each component of the project.

6. Conclusion

The ISS Tech Team is making progress on all areas of the design and construction of the rocket and payload. Component acquisition is commencing in areas where the design has been finalized, allowing for the beginning of construction of sections which have not yet started. Additionally, progress on construction of the rocket and recovery system proceeds well enough for a first test flight in mid to late November. The complexity of the project, including multiple systems that have never been attempted together, is one of the most daunting technical projects attempted by any Illinois Space Society Technical Project.

Appendices

A. NAR Safety Code

B. MSDS

A. NAR Safety Code

High Power Rocket Safety Code
Provided by the National Association of Rocketry

1. Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.

2. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.

3. Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.

4. Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. If my rocket has onboard ignition systems for motors or recovery devices, these will have safety interlocks that interrupt the current path until the rocket is at the launch pad.

5. Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

6. Launch Safety. I will use a 5-second countdown before launch. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table, and that a means is available to warn participants and spectators in the event of a problem. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable.

7. Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that

dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 if the rocket motor being launched uses titanium sponge in the propellant.

8. Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.

9. Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

10. Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater.

11. Launcher Location. My launcher will be at least one half the minimum launch site dimension, or 1500 feet (whichever is greater) from any inhabited building, or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

12. Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

13. Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

B. MSDS

For ease of use, MSDS sheets for all relevant materials can be found on the project website, at

http://www.ae.illinois.edu/iss/?id=usli